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Seasonal Fluctuations in the Surface Salinity off the North Coast of Java

by

RD. E. SOERIAATMADJA

The Subtropical Lower Water between the Philippines and Irian (New Guinea)

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NOTICE.

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SEASONAL FLUCTUATIONS IN THE SURFACE SALINITY OFF THE NORTH COAST OF JAVA

by

Rd. E. SOERIAATMADJA

SUMMARY

The division of the region investigated according to P. CH. VEEN is redescribed.

The micro salinity titration by means of the method described by G. H. ARNOLD with an accuracy of 0.1 $^0/_{00}$ was used for this investigation. This technique was adopted because of the large number of observations, and was sufficiently accurate since salinity in these waters varies widely.

The annual range in salinity is large, caused by a considerable discharge of fresh water from the many big and small rivers, especially in the rainy-season as well as by the inequality of salinity of the ocean-waters coming from the East, and the South China Sea water coming from the West, during the dry and wet-sason respectively.

In the east-monsoon, the eastern section is covered with ocean water over 34.0 $^0/_{00}$ and the western section with mixed waters ranging between 31.5 $^0/_{00}$ and 34.0 $^0/_{00}$, while in the west-monsoon, the area is covered with mixed water less than 32.5 $^0/_{00}$.

ZUSAMMENFASSUNG

Die Einteilung des untersuchten Gebietes nach P. CH. VEEN wird beschrieben. Die von G. H. ARNOLD beschriebene Mikro-Methode zur Bestimmung des Salzgehaltes mit einer Genauigkeit von 0,1$^0/_{00}$ wurde für die Untersuchungen benutzt. Dies war nötig wegen der grossen Zahl der untersuchten Proben und genügend genau wegen der grossen Schwankungen des Salzgehaltes.

Die Jahresschwankung des Salzgehaltes ist gross wegen des erheblichen Abflusses von Frischwasser aus den zahlreichen grösseren und kleineren Flüssen, besonders während der Regenzeit, als auch wegen des Unterschiedes im Salzgehalt zwischen den ozeanischen Wassermassen, die

während der Trockenzeit vom Osten vordringen, und den Wassermassen der Süd-China-See, die während der Regenzeit von Westen kommen. Während des Ost-Monsuns sind die östlichen Teile mit ozeanischem Wasser von über 34‰ bedeckt, und die westlichen Teile mit Mischwasser zwischen 31,5‰ und 34‰, während zur Zeit des West-Monsuns das gesammte Gebiet von Mischwasser mit weniger als 32,5‰ angefüllt ist.

ICHTISAR

Pembagian daerah jang diselidiki menurut P. CH. VEEN telah diuraikan lagi.

Tritasi micro dari kadar garam dengan tjara jang diuraikan oleh G. H. ARNOLD dengan ketelitian 0.1‰ telah dipergunakan dalam penjelidikan ini. Teknik ini dipakai, berhubung dengan banjaknja pemeriksaan dan teknik mana tjukup teliti, oleh karena kadar garam diperairan ini mempunjai perobahan jang agak besar.

Pergojangan kadar garam tiap tahun adalah besar, disebabkan sangat banjaknja pemasukan air tawar dari sungai-sungai besar dan ketjil, teristimewa dalam musim hudjan dan ketidak samaan kadar garam air lautan jang berasal dari Timur dan air Laut Tiongkok Selatan jang berasal dari Barat, masing-masing selama musim kemarau dan musim hudjan.

Dalam musim Timur, bagian sebelah timur diliputi oleh air lautan lebih dari 34.0‰ dan bagian sebelah barat oleh tjampuran air antara 31.5‰ dan 34.0‰, sedangkan dalam musim barat, seluruh daerah diliputi oleh tjampuran air kurang dari 32.5‰.

In 1949 P. CH. VEEN, oceanographer of the Lembaga Penjelidikan Laut (Institute of Marine Research) Djakarta, started with an extensive survey of surface salinities over the whole area of the Indonesian Archipelago. This survey was made possible through the courtesy and voluntary co-operation of all Captains and Officers of the private navigation companies and the government Navigation Service and lighthousekeepers, who participate, in the collection of the thousands of watersamples.

As a result of this work P. CH. VEEN published, in 1951, charts for the mean surface-salinities for the 12 months March 1949 — February 1950, whereas J. D. F. HARDENBERG and the author, in 1955, made a continuation of the same charts for the months March 1950 — February 1953. In 1953 P. CH. VEEN gave a summary of all oceanographic data collected by our laboratory and the previous research workers, by drawing monthly charts of the mean salinity. Since January 1955 monthly charts of surface

salinities in Indonesian and surrounding waters were made regularly by K. WYRTKI, who became oceanographer of the Lembaga Penjelidikan Laut in October 1954. The same author published, in 1956, an introduction to the regular monthly charts of surface salinity in Indonesian and adjacent waters.

For those who are not in possession of the above mentioned papers a brief review on the methodology is considered to be necessary here.

The whole area of the survey is divided in twenty-minute (20′) squares, which means that every square degree (1°) on the chart is subdivided into nine squares of twenty-minutes each. These twenty-minute squares are numbered from 1 to 9 running from West to East and from the Equator toward the Poles.

Each of these squares is numbered so that the actual position of the square on the chart can easily be read from the number. These numbers consist of five figures preceded by a prefix N or S standing for North or South latitude. The first two figures indicate the degree latitude of the square. If the degree is less than 10° it is preceded by a zero. The following two figures indicate the degree of longitude of the square. If the degree is 100° or over, the initial "one" is omitted. The last figure indicates the subdivision of the square.

For example (fig. 1 and 2).

N. 01976 means the square limited by N. latitude 1°— 20′ and 1°— 40′ and E. longitude 97°— 40′ and 98°— 00′, whereas N. 0197 means the square bounded by N. latitude 1°— 2° and E. longitude 97° and 98°.

S. 07158 means the square limited by S. latitude 7°— 40′ and 8°— 00′ and E. longitude 115°— 20′ and 115°— 40′, whereas S. 0715 means the square bounded by S. latitude 7° and 8° and E. longitude 115° and 116°.

All data from the observations are recorded in a card index. A separate card bearing the number of the square is taken for each square. All data pertaining to the same square are entered on the same card. A separate card is used for each month's observations. As soon as all samples of a certain month are complete, averages are calculated. The results are plotted on the charts and isohalines can be drawn.

The salinities are determined by the Knudsen method, modified by G. H. ARNOLD (1951), which only needs 1 ml. of sample and which has an accuracy of 0.1 $^{0}/_{00}$. Titrations are made against standard seawater from Copenhague. The speed of this method is necessary, because of the large number of observations. The accuracy is just sufficient for the purpose of this investigation.

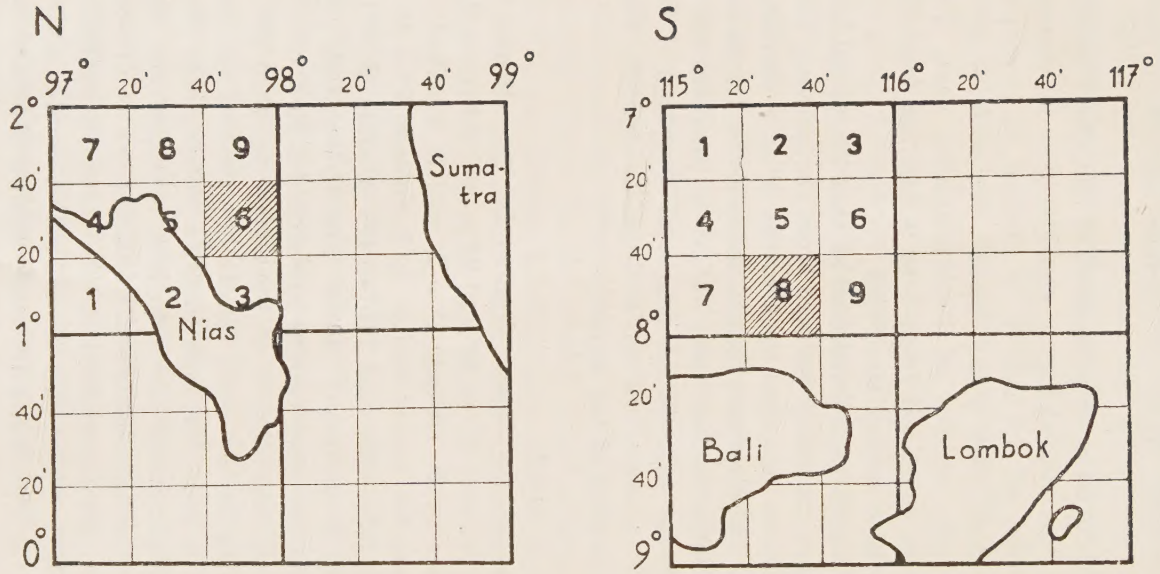

FIG. 1 and 2 : Sample for the division of the 1°— squares and 20'— squares.

The present paper is based on the data 1949—1955 consisting of 30,739 observations divided in 18 squares each of one degree, which were collected by our Institute (table 1). The area surveyed includes the region between S. latitude 5° and 7°, and extending from the Sunda Strait to E. longitude 115°, occupying the whole southern part of the Java Sea (fig. 3).

The Java Sea has a rectangular shape and is bordered on the West by South Sumatra and Sunda Strait, on the North by South China Sea and Kalimantan (Borneo), on the East by Flores Sea and on the South by Java. It is a shallow sea and the bottom shows a slight gradual slope from the coast to the centre and from West to East, so that in general the western section shows the lowest and the eastern section the highest depths with an average of about 50 meters in the middle.

Compared with the range in surface salinity of the occeans, which is subject to only small annual variation, the mean range in salinity of the surface waters of the Java Sea in the centre is large, from 30.8 $^0/_{00}$ to 34.3 $^0/_{00}$ in the eastern section, and from 30.6 $^0/_{00}$ to 32.6 $^0/_{00}$ in the western section or a mean annual range of 3.5 $^0/_{00}$ and 2.0 $^0/_{00}$, respectively. This is namely caused by a considerable discharge of fresh water from the many big and small rivers of Kalimantan, South Sumatra and Java, and by the changes of the current systems due to the monsoons.

The yearly variation of the surface salinity of the whole Java Sea would be the same, if the waterbody coming from the shallow South China Sea in the west-monsoon and the waterbody coming from the Flores Sea and Macassar Strait in the east-monsoon, were equal in salinity. This asymetry in salinities results in the yearly variation in the eastern part of the Java Sea being much greater than that of the western part.

Fig. 4 and 5 represent isopleths of the surface salinities of the region investigated. As in the previous papers the author begins with his diagrams in March, in accordence with the changing windstrength and wind-directions occuring in Indonesia.

March, April and May is the time wherein the west-monsoon gradually decreases in strength and is by and by replaced by the counteracting east-monsoon. At the end of this period, ocean water from the East approaches the Java Sea, pushing the less saline water in a westward and landward direction.

During the period of the full east-monsoon, June, July and August, the time of the strongest wind coming from the East, a westgoing current prevails, adducing Indian Ocean water over 34.0 $^0/_{00}$ from the Flores Sea. At the same time, Pacific Ocean water penetrates the Sulawesi Sea

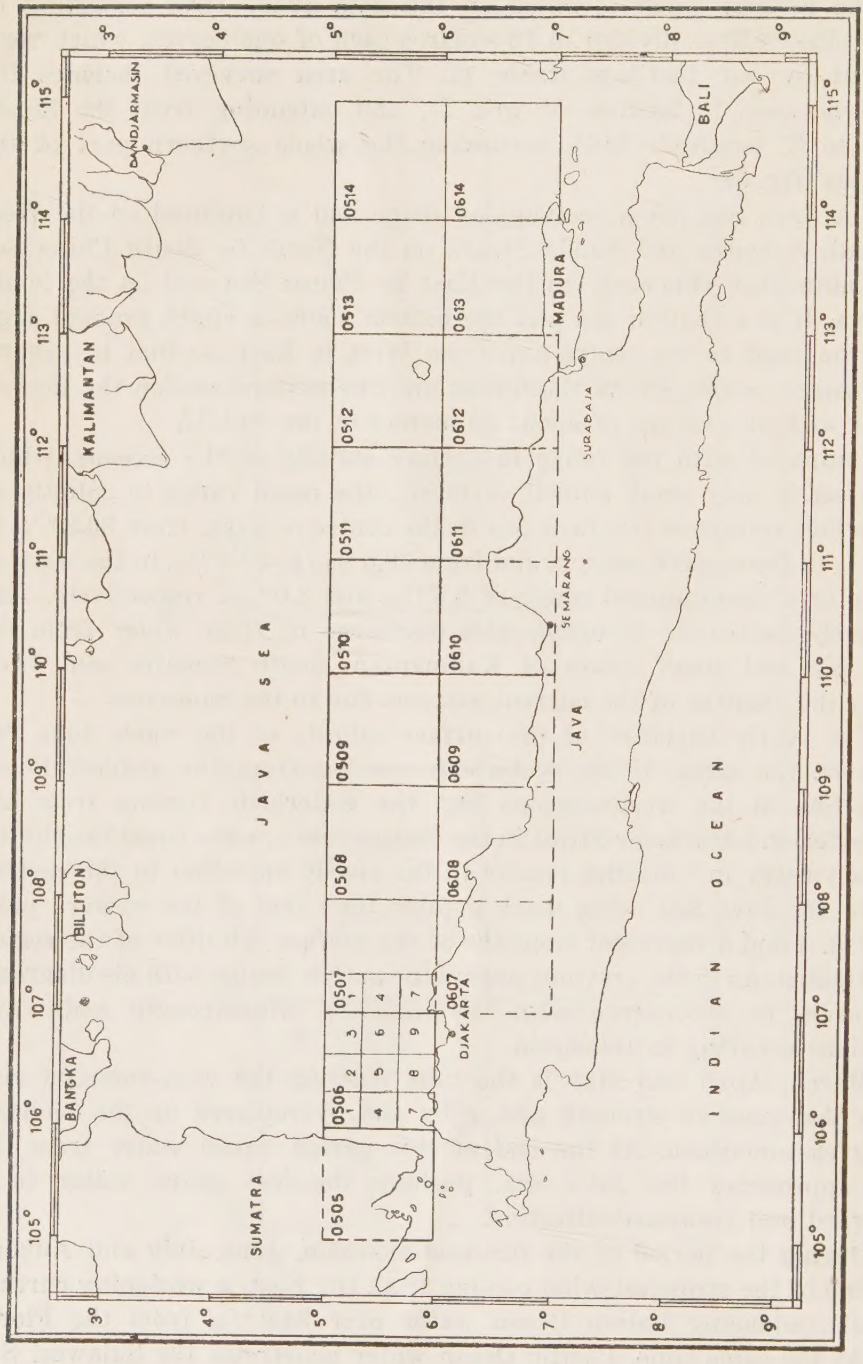

FIG. 3 : Area under investigation with 1°— squares used.

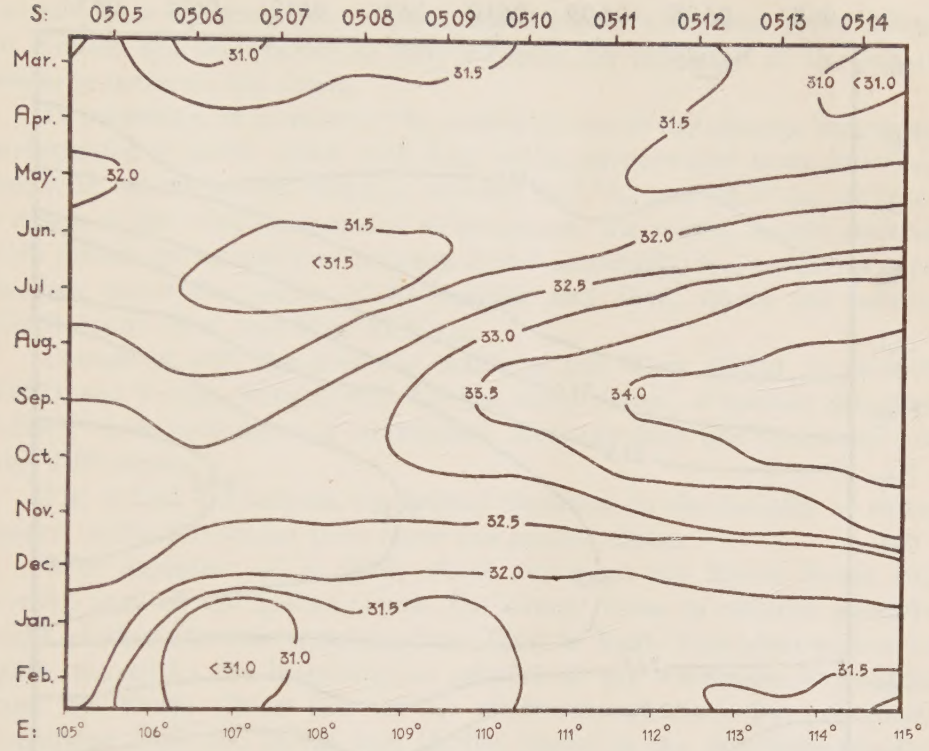

FIG. 4 : Isopleths of surface salinity along the north-coast of Java.

and Macassar Strait and meets the Indian Ocean water in August. The waterbody with high salinity thus formed reaches its maximal westward movement in the central part of the Java Sea off Semarang in September. At the same time and in October, the more saline water, gradually mixed with less saline water moves landward and westward, so that the salinity gradually decreases as it approaches the western part of the Java Sea and the coasts of Kalimantan and Java.

During September, October and November the situation is opposite to that occuring in March, April and May.

The succeeding period December, January and February, is the time of the full west-monsoon, wherein a strong rain-laden wind blows from the West. An east-going current prevails, adducing water from the South China Sea and pushing the oceanic water far eastward. As already mentioned, the waterbody coming from the shallow southern part of the South China Sea is less saline. Besides, as a result of the rainy-season, a considerable discharge of fresh water from all the rivers takes place, the

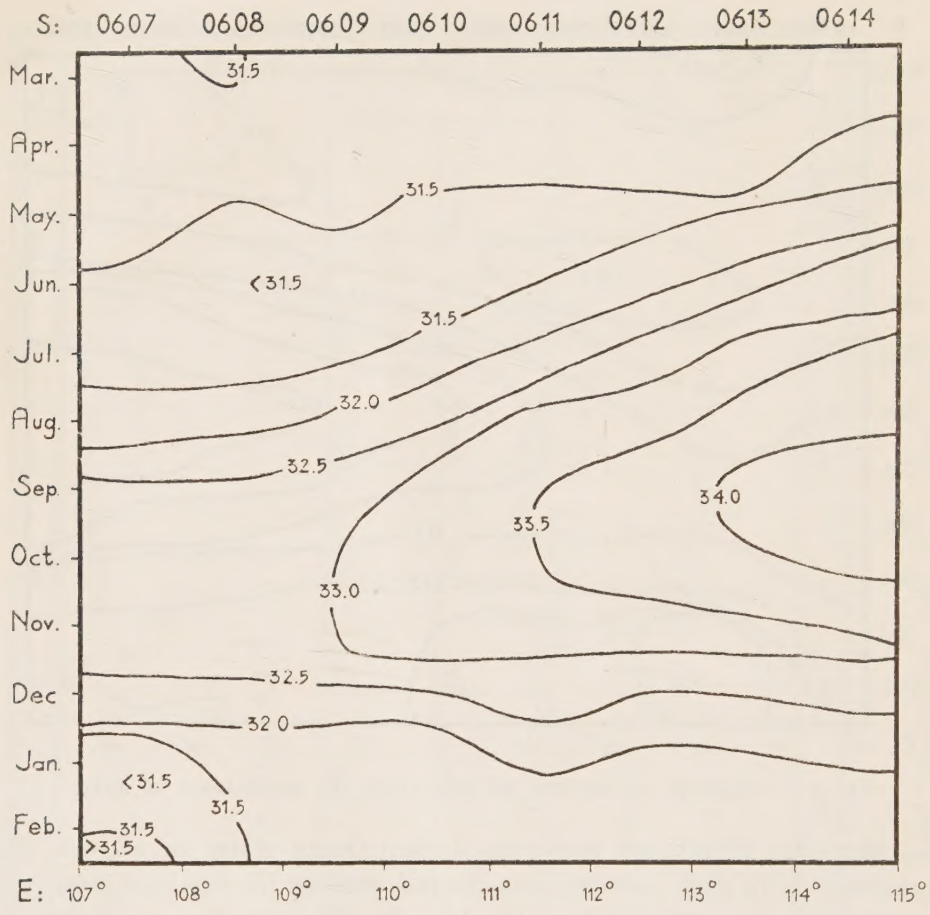

FIG. 5 : Isopleths of surface salinity along the north-coast of Java.

discharge from the rivers of Kalimantan being more than that from the rivers of Java. This fresh water spreads over the more saline water in the middle and gradually mixes with the latter. As a result of these two circumstances, a sudden drop in salinity is found in this period. The salinity in the region investigated varies between 31.0 $^0/_{00}$ and 32.5 $^0/_{00}$ except in the bay of Djakarta (S. 0506) and off Bandjarmasin (S. 0514) where, because of heavy river discharges, water less than 31.0 $^0/_{00}$ can be found, compared to 31.5 $^0/_{00}$ to over 34.0 $^0/_{00}$ during the east-monsoon.

Despite its proximity to the Indian Ocean, no salinities over 33.0 $^0/_{00}$ were observed in the Sunda Strait. This can be attributed, according to the Eastern Archipelago Pilot Vol. II Chap. III, to a constant south-west

current from the Java Sea to the Indian Ocean which takes place during all months but November, so that virtually no influence of the Indian Ocean is noted in the strait.

In summary, as a result of the east-monsoon or dry-season, the region investigated is partly filled with high saline ocean-water (over 34.0 $^0/_{00}$) and with mixed waters ranging between 31.5 $^0/_{00}$ and 34.0 $^0/_{00}$, while as a result of the west-monsoon or rainy-season, the region is only covered with mixed waters ranging between 31.0 $^0/_{00}$ and 32.5 $^0/_{00}$ except in some squares under the coasts of Kalimantan and Java, where the salinity distributions show less than 31.0 $^0/_{00}$.

Compared with the previous charts of VAN WEEL (1930), G. SCHOTT (1937) and P. CH. VEEN (1953) for the same region, a certain principal pattern of the isohalines is maintained, although here and there one will find differences.

Fig. 6 and 7 illustrate the annual variation in the salinity of every square, while the dotted lines show the annual mean.

With exception of S. 0505, which represent the Sunda Strait and a small part of the Indian Ocean, the annual mean of salinity shows a slight gradual increase, running from West to East. This phenemenon is, again, caused by the inequality of salinity of the watermass emanating from the South China Sea in the west-monsoon, and the watermass emanating from the Indian and Pacific Ocean in the east-monsoon into the Java Sea, as stated above.

An increase in salinity in the eastern section starts in the period March — May, when the east-going current gradually decreases and finally is replaced by an inverse current, which means an invasion of the ocean-water into the Java Sea. This waterbody with high salinity over 34.0 $^0/_{00}$ reaches its maximum advance at the end of the succeeding full east-monsoon (June — August) at longitude 110° E. between latitude 5°— 6° S., and at longitude 113° E. between latitude 6°— 7° S. This ocean-water advances further westward and landward, mixing with less saline water. As may be expected, one sees the gradual displacement of the highest salinity of every square from September in the eastern section to November in the western section, the time wherein the opposite of the happening is found in the period March-May.

The first outburst of rain in December, being the beginning of the full west-monsoon, causes the sudden drop of salinity in the western section.

In general, the difference between the annual mean and the highest salinity is much greater than that between the annual mean and the

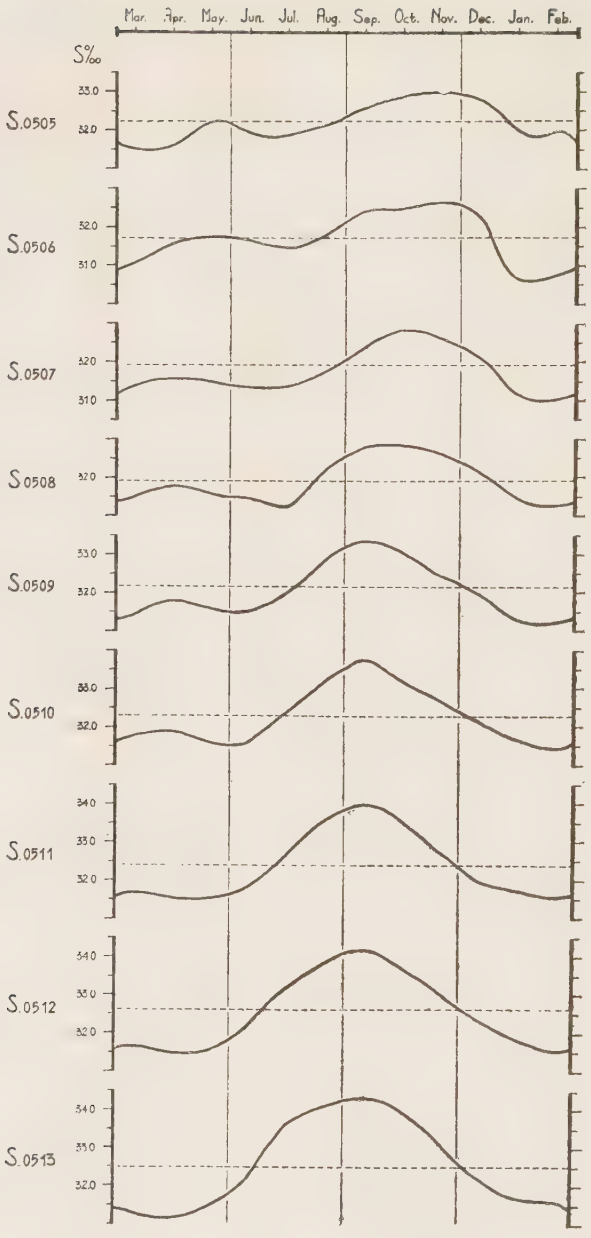

FIG. 6: The annual variation and the annual mean of salinity for every 1°— square.

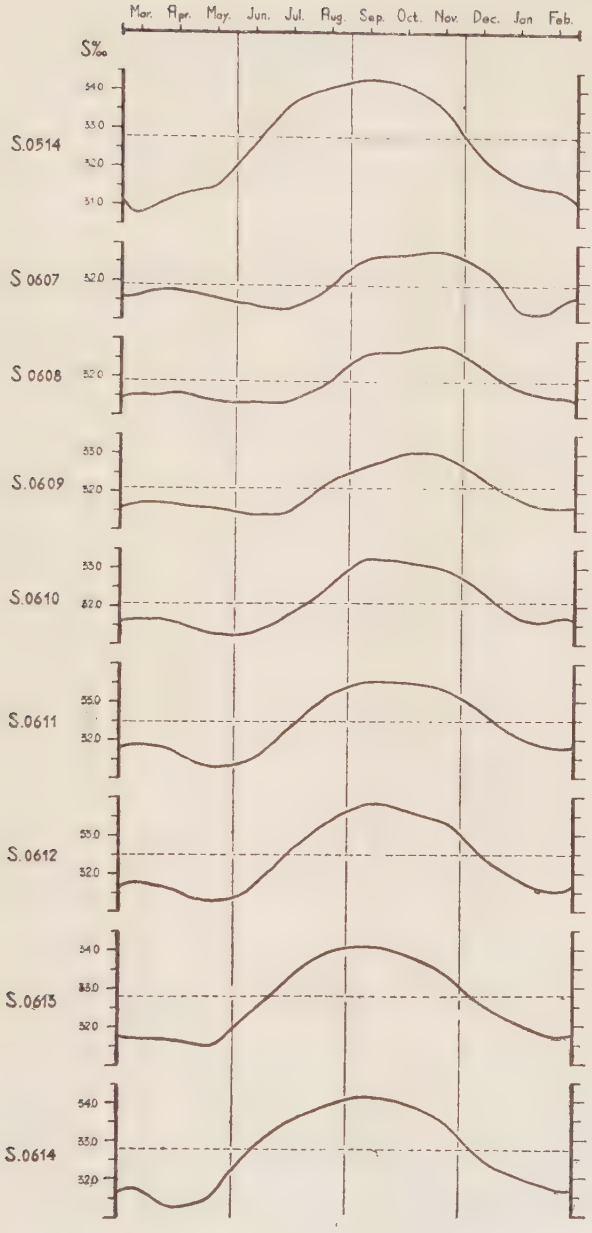

FIG. 7: The annual variation and the annual mean of salinity for every 1°— square.

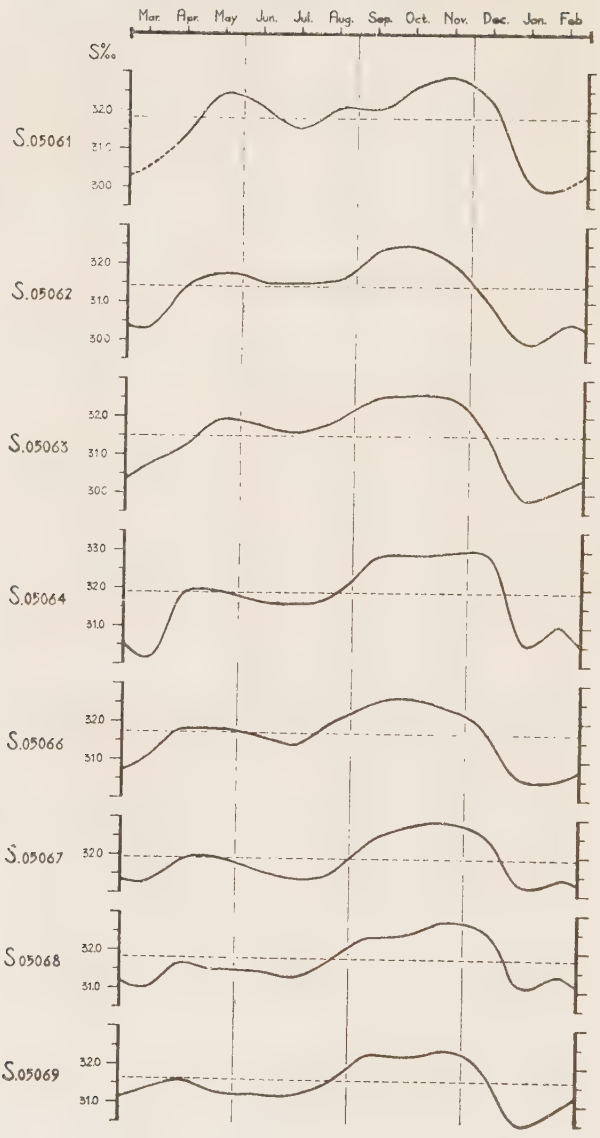

FIG. 8: The annual variation and the annual mean of salinity for every 20'— square off the bay of Djakarta.

lowest salinity, as is seen in the diagrams. So the salinity of the region is above annual mean only during 5 months of the year.

To gain an insight into the fluctuations of the surface salinities in every twenty-minute square off the bay of Djakarta, fig. 8 and 9 were prepared. Because of the few observations, no diagram is made for the square S. 05065. Although the diagrams show irregularities, a principal

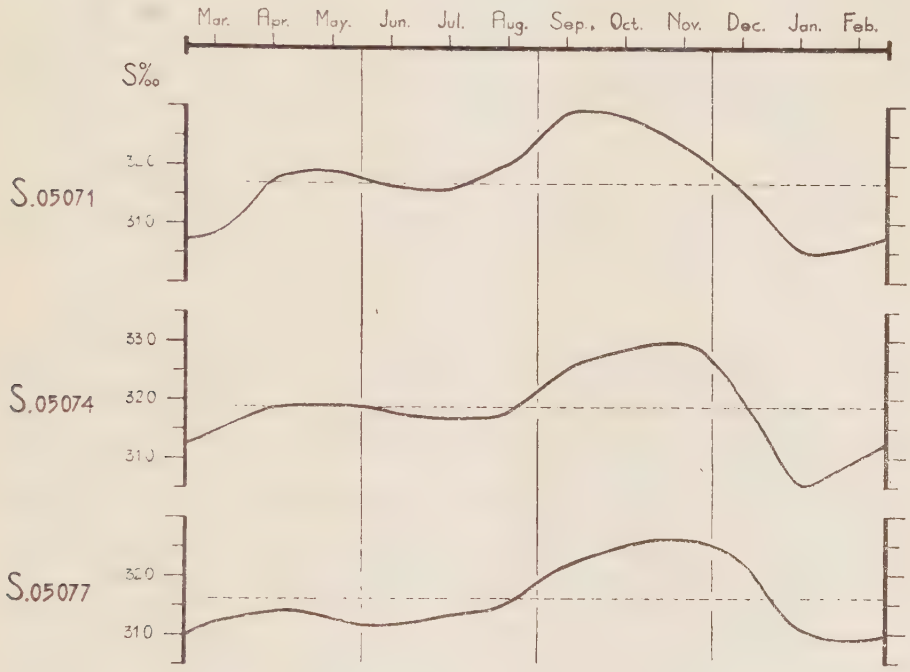

FIG. 9: The annual variation and the annual mean of salinity for every 20'— square off the bay of Djakarta.

pattern is maintained. The highest salinity is found in the months of October — November and the lowest in the period January — March. An extreme drop in salinity as is seen in the coastal squares (05061 and 05064) in these months could be attributed to a considerable discharge of fresh water and probably to the continue strong south-west current in this section, as stated above. Irregular fluctuations due to the influence of the rainy-season are found in the advancing months.

Acknowledgments

Great acknowledgment goes to Mr. P. Ch. Veen, former oceanographer of the Lembaga Penjelidikan Laut at Djakarta, for his initiative in developing the Marine Research in Indonesia and his invention of the easy methodology.

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Finally to Dr. K. Wyrtki, present oceanographer of Lembaga Penjelidikan Laut at Djakarta, for his kind critical advices in preparing this paper.

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TABLE 1. NUMBER OF OBSERVATIONS PER SQUARE DEGREE FOR EACH MONTH 1949-1955

Latitude-South.

Month	0505	0506	0507	0508	0509	0510	0511	0512	0513	0514	0607	0608	0609	0610	0611	0612	0613	0614
March	79	366	275	127	74	75	82	54	77	70	16	164	212	244	255	260	129	55
April	102	338	285	132	73	55	47	36	73	56	5	154	207	245	242	224	138	63
May	101	403	285	122	70	68	65	42	98	67	15	195	200	217	222	215	139	79
June	128	309	238	108	66	50	63	49	65	73	5	162	181	210	216	213	155	69
July	158	355	280	136	88	65	53	61	78	85	12	217	227	269	241	275	157	69
August	116	344	328	141	94	73	63	43	53	96	9	218	253	260	267	267	187	87
September	97	289	276	111	75	45	53	34	61	77	9	192	201	182	229	234	152	64
October	116	390	305	120	103	75	73	34	49	82	10	226	230	246	268	263	144	59
November	103	379	280	111	75	50	50	46	78	72	3	203	232	248	271	268	150	68
December	89	314	278	127	70	63	51	36	53	77	10	187	224	238	257	169	123	55
January	111	358	255	121	61	49	49	29	49	48	8	208	203	240	221	239	113	47
February	106	379	233	94	63	49	41	26	55	37	5	185	189	214	226	218	97	54
TOTAL	1306	4224	3318	1450	912	717	690	490	789	840	107	2311	2559	2813	2915	2845	1684	769

TABLE 2. MEAN SURFACE SALINITY AND NUMBER OF OBSERVATIONS PER SQUARE DEGREE FOR EACH MONTH

Latitude-South.

Year	Square degree	March		April		May		June		July		August		Sept.		October		Nov.		Dec.		January		Febr.	
		S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No
1949	0505	—	—	32,8	1	32,3	6	31,0	7	32,3	3	32,5	11	33,1	9	33,1	11	32,8	9	32,6	19	—	—	—	—
„	0506	30,8	27	31,7	33	31,5	13	31,4	28	31,5	19	31,8	25	32,8	26	33,0	22	32,9	31	32,4	50	30,2	5	31,5	5
„	0507	30,8	4	31,9	10	32,2	10	31,4	18	31,2	40	32,9	45	32,8	40	33,2	59	32,8	50	32,7	58	—	—	—	—
„	0508	31,5	11	31,7	8	31,8	9	31,3	7	31,5	7	32,5	14	33,0	16	33,2	22	32,8	21	32,4	21	31,1	5	31,1	4
„	0509	31,9	4	32,1	5	32,3	5	31,2	6	32,3	8	33,4	14	33,2	9	33,4	17	32,7	23	32,1	13	—	—	—	—
„	0510	31,7	2	32,1	2	31,5	2	31,5	1	32,7	5	33,3	3	33,6	7	33,2	14	32,8	11	32,4	11	—	—	—	—
„	0511	—	—	—	—	—	—	31,9	1	32,8	1	33,9	1	—	—	—	—	32,9	2	32,2	3	—	—	—	—
„	0512	—	—	—	—	30,0	1	32,6	1	33,4	1	—	—	—	—	—	—	—	—	31,8	3	—	—	—	—
„	0513	31,4	4	30,4	8	30,5	10	31,7	20	33,5	6	34,0	6	34,0	8	34,1	8	33,2	10	—	—	—	—	—	—
„	0514	—	—	—	—	—	—	32,6	3	33,7	5	34,0	5	34,2	6	34,4	4	34,2	3	32,6	1	—	—	—	—
„	0607	—	—	—	—	—	—	—	—	30,7	1	31,2	1	32,6	2	32,9	1	—	—	—	—	—	—	—	—
„	0608	—	—	—	—	—	—	30,8	7	31,2	31	31,8	34	32,6	29	33,3	35	33,1	31	32,7	33	—	—	—	—
„	0609	—	—	—	—	—	—	31,0	2	31,4	29	32,1	29	33,0	25	33,3	33	32,9	68	32,7	39	—	—	—	—
„	0610	—	—	—	—	—	—	30,9	3	31,7	28	32,6	31	33,1	30	33,3	34	33,3	30	33,1	35	—	—	—	—
„	0611	32,0	1	32,3	1	31,7	2	31,7	3	32,3	36	33,1	40	33,6	40	33,5	49	33,3	37	33,2	43	—	—	—	—
„	0612	31,8	3	32,0	3	31,1	8	31,7	9	32,2	32	33,3	34	33,8	30	33,8	48	33,1	42	—	—	—	—	—	—
„	0613	31,9	3	31,4	8	31,1	6	32,3	9	32,9	16	33,9	14	33,9	14	34,0	15	33,2	8	33,2	8	—	—	—	—
„	0614	31,5	2	—	—	32,0	2	32,5	5	32,9	6	33,7	2	33,8	3	34,0	2	33,8	1	32,9	5	—	—	—	—
1950	0505	31,9	38	31,6	15	31,7	32	32,0	40	31,7	37	31,7	28	32,3	15	32,3	22	32,8	9	33,0	27	32,7	27	31,9	32
„	0506	31,0	61	31,4	40	31,4	49	31,7	70	31,3	84	31,6	74	32,0	50	32,0	58	32,7	51	32,6	58	31,2	56	30,6	59
„	0507	31,3	53	31,5	51	31,6	42	31,4	37	31,2	56	31,5	74	32,0	43	32,4	49	32,3	42	32,3	60	31,6	45	31,2	43
„	0508	31,4	23	31,7	18	31,8	19	31,5	15	31,4	39	31,9	42	32,5	20	32,7	19	32,4	21	32,0	33	31,7	30	31,5	25
„	0509	31,3	10	31,5	7	31,4	17	31,4	8	31,4	21	32,8	14	33,0	15	32,9	16	32,2	13	31,5	22	31,2	14	31,5	13
„	0510	31,6	9	31,5	10	31,1	15	31,3	9	31,9	7	32,9	18	33,7	6	33,0	13	32,4	7	31,6	13	31,7	10	31,9	6
„	0511	31,8	9	31,7	9	30,9	3	31,5	7	32,0	5	33,2	13	33,9	5	33,4	11	32,5	6	31,6	11	31,7	2	32,0	4
„	0512	31,5	13	31,6	8	31,1	5	32,0	8	32,3	7	33,6	6	34,0	6	33,7	6	32,9	17	32,2	12	31,9	5	31,3	7
„	0513	31,1	16	31,4	21	31,7	5	—	—	33,0	14	33,7	3	34,0	10	33,7	5	32,8	18	32,0	21	32,0	6	31,6	11
„	0514	31,2	10	31,4	8	31,5	8	32,1	8	33,5	7	34,0	16	34,3	16	34,1	14	33,4	9	32,2	21	31,4	2	31,5	5
„	0607	31,8	2	—	—	31,7	2	31,5	2	31,9	2	—	—	31,6	1	—	—	—	—	—	—	—	—	—	—

„	0609	31,4	39	31,7	47	31,6	33	31,3	38	31,3	50	32,3	52	32,3	41	32,4	38	—	—	32,2	50	32,0	37	32,0	43
„	0610	31,5	43	31,7	50	31,2	27	30,9	37	31,6	62	32,1	41	32,8	39	32,6	33	32,5	49	31,9	40	31,8	33	31,8	37
„	0611	31,9	43	31,5	46	31,0	40	31,1	42	32,3	45	32,8	63	33,5	49	33,5	41	32,9	36	32,2	46	32,1	40	32,0	44
„	0612	31,4	45	31,5	43	31,1	25	31,4	39	32,4	47	32,9	61	33,3	46	33,6	37	33,0	35	32,3	38	32,2	45	31,8	45
„	0613	31,8	22	31,8	16	31,4	16	31,8	18	32,9	18	33,7	27	34,0	26	33,8	19	33,4	30	32,4	24	32,5	12	31,8	10
„	0614	31,7	3	31,7	6	31,1	9	32,3	7	33,0	7	33,8	18	34,0	8	34,0	12	33,4	13	32,7	9	32,8	3	—	—
1951	0505	—	—	31,9	19	31,7	10	31,7	13	31,5	18	31,2	14	32,0	8	32,6	20	32,2	23	32,1	10	31,3	30	32,4	23
„	0506	31,2	60	32,0	70	31,6	78	31,1	55	30,9	76	31,0	71	32,0	64	31,6	123	32,1	92	31,8	69	30,0	60	30,7	75
„	0507	31,5	46	31,8	42	31,3	46	30,9	52	30,9	39	31,1	52	31,8	54	32,1	54	32,3	47	32,2	37	30,7	59	30,7	51
„	0508	31,3	20	31,7	21	31,2	26	31,1	25	30,7	30	32,0	18	32,4	15	32,3	28	32,4	13	32,3	26	31,0	27	31,0	21
„	0509	31,3	12	31,0	10	31,3	12	31,3	11	31,5	9	32,3	14	33,1	9	32,4	25	32,2	8	32,3	11	31,1	9	30,9	19
„	0510	31,6	9	30,8	7	31,2	13	31,3	10	31,8	5	32,8	6	33,7	6	32,9	15	32,3	6	32,3	13	31,4	5	31,2	8
„	0511	31,2	12	30,8	10	31,0	18	31,5	20	32,2	5	33,2	10	34,0	18	33,7	15	32,9	5	32,3	10	31,5	10	31,5	4
„	0512	31,3	3	30,8	6	31,3	8	31,9	14	33,1	4	33,7	6	33,9	5	33,8	12	32,6	6	32,2	8	31,4	4	31,6	2
„	0513	31,0	9	30,9	15	31,7	17	32,0	15	33,3	6	33,8	11	34,2	14	34,0	13	33,4	18	31,9	5	31,4	14	31,1	13
„	0514	30,8	14	31,5	13	32,1	13	32,5	23	33,3	21	33,9	14	34,2	14	34,2	24	34,1	11	32,3	22	31,5	13	31,2	12
„	0607	31,4	1	31,6	1	—	—	—	—	31,0	3	31,4	1	31,9	2	32,4	1	—	—	32,3	2	31,1	1	30,5	1
„	0608	31,4	29	31,5	31	31,0	37	31,1	33	30,8	34	31,3	37	32,2	44	32,5	35	32,5	42	32,4	34	31,2	30	31,1	34
„	0609	31,7	40	31,4	40	31,1	43	30,8	35	30,8	37	31,7	48	32,5	51	32,9	40	32,6	46	32,3	43	31,5	35	31,3	38
„	0610	31,6	37	31,2	51	30,7	50	30,7	43	31,3	47	32,3	44	32,6	5	32,9	51	32,5	34	32,1	53	31,6	58	31,4	44
„	0611	31,6	46	30,9	45	31,0	54	31,3	41	32,0	44	33,0	51	33,6	49	33,3	56	33,1	47	32,6	44	31,8	35	31,5	44
„	0612	31,5	48	30,9	40	31,0	54	31,5	56	32,4	47	33,3	53	33,9	63	33,5	46	33,2	43	32,3	49	31,4	63	31,4	38
„	0613	31,4	23	31,0	26	31,7	27	32,3	38	33,0	34	33,7	37	34,1	33	33,9	39	33,0	23	32,4	37	31,6	29	31,6	24
„	0614	31,7	6	31,1	8	31,9	13	32,7	18	33,2	9	33,7	15	34,1	14	34,0	11	33,4	10	32,1	9	31,5	8	31,4	10
1952	0505	30,7	7	31,7	18	31,4	7	31,7	18	31,7	37	31,7	33	32,5	29	33,0	20	33,3	31	32,7	21	32,5	20	30,8	8
„	0506	30,4	69	31,3	74	31,8	85	31,4	59	31,3	68	31,8	79	32,7	75	33,2	95	32,9	109	32,1	73	31,0	73	30,2	72
„	0507	31,1	64	31,4	48	31,4	59	31,2	64	31,3	54	31,9	57	32,8	71	33,2	68	33,0	67	31,8	53	31,5	39	30,9	50
„	0508	31,4	32	31,5	23	31,3	19	31,2	25	31,5	22	32,4	22	33,0	30	33,0	21	32,9	23	31,7	22	31,8	21	31,4	22
„	0509	31,3	26	31,7	11	31,1	12	31,3	23	32,4	21	33,4	16	33,9	27	33,7	19	32,5	14	31,8	10	31,7	7	31,2	13
„	0510	31,7	27	31,8	10	31,3	7	31,5	17	32,9	10	34,0	10	34,2	20	33,7	13	32,7	17	32,2	17	31,9	13	31,4	20
„	0511	31,7	16	31,6	13	31,3	20	32,0	18	33,5	9	34,3	11	34,3	16	34,0	19	33,1	12	32,1	13	31,9	13	31,4	15
„	0512	31,7	17	31,4	9	31,2	9	32,2	16	33,6	9	34,2	8	34,3	16	33,5	8	33,6	9	32,5	6	32,0	8	31,5	9
„	0513	31,2	22	31,0	5	31,5	18	32,5	14	34,1	29	34,4	15	34,5	21	34,2	9	33,4	19	32,5	20	31,6	6	31,6	10
„	0514	31,2	12	31,0	13	31,9	14	32,4	18	34,2	24	34,3	22	34,4	26	34,4	12	33,8	21	32,5	26	31,6	12	31,5	8
„	0607	31,0	4	31,8	1	31,4	7	31,0	2	31,3	4	32,0	2	33,3	1	32,9	5	—	—	32,8	2	31,6	1	—	—

MEAN SURFACE SALINITY AND NUMBER OF OBSERVATIONS PER SQUARE DEGREE FOR EACH MONTH

Latitude-South.

Year	Square degree	March		April		May		June		July		August		Sept.		October		Nov.		Dec.		January		Febr.	
		S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No	S°/₀₀	No
1952	0608	31,3	43	31,4	35	31,4	49	31,3	40	31,4	56	32,2	36	32,9	28	33,4	46	33,0	49	32,3	35	31,7	33	31,5	39
,,	0609	31,3	47	31,6	36	31,5	42	31,2	45	31,5	47	32,6	45	33,0	31	33,7	40	33,2	49	32,2	36	31,9	33	31,5	36
,,	0610	31,5	58	31,8	39	31,2	43	31,2	50	32,1	54	32,9	44	33,4	39	33,7	49	33,6	57	32,6	47	31,5	46	31,5	50
,,	0611	31,9	53	31,7	43	31,1	37	31,4	56	32,6	50	33,9	52	33,9	43	34,0	56	33,9	58	33,0	59	32,1	44	32,0	51
,,	0612	31,8	47	31,7	31	31,3	47	31,5	50	33,3	64	34,2	49	34,2	40	34,1	52	33,7	70	32,6	36	32,0	43	31,8	41
,,	0613	31,7	23	31,7	21	31,3	31	32,6	39	33,9	36	34,2	43	34,3	37	34,4	29	33,9	42	33,0	32	32,1	19	31,5	19
,,	0614	31,7	12	31,0	20	31,7	22	33,0	16	34,1	14	34,1	22	34,5	16	34,4	12	33,8	19	33,3	12	32,4	8	31,6	17
1953	0505	31,7	28	32,1	36	32,2	34	32,1	40	32,3	36	33,7	25	32,5	29	33,5	37	33,3	28	33,2	8	31,5	25	32,2	39
,,	0506	31,1	96	31,4	85	31,7	114	31,9	54	31,9	57	32,4	58	33,1	55	33,4	55	32,8	59	32,5	32	30,1	104	31,4	114
,,	0507	31,5	68	31,7	87	31,4	68	31,8	51	32,0	54	32,3	52	33,1	36	33,4	34	32,7	44	32,5	43	30,8	75	31,2	56
,,	0508	31,6	28	31,7	35	31,8	36	31,9	22	31,0	23	32,7	30	33,4	15	33,6	19	32,5	19	32,7	13	31,2	17	31,4	11
,,	0509	31,5	18	31,9	28	31,9	18	31,9	10	32,1	21	33,0	22	33,7	9	33,8	13	32,8	7	32,6	10	31,2	11	31,4	8
,,	0510	31,9	24	32,2	17	31,9	24	32,1	9	32,5	31	33,4	24	34,1	4	33,7	14	33,4	7	32,9	5	31,4	10	31,9	5
,,	0511	32,1	24	32,2	9	32,1	18	32,0	14	32,9	24	33,6	17	34,1	6	34,1	17	33,6	15	32,4	2	31,7	10	31,9	10
,,	0512	31,8	17	32,1	8	31,8	14	32,4	8	33,3	35	33,8	18	34,5	3	34,4	7	33,8	8	33,1	4	32,0	7	31,8	7
,,	0513	31,7	23	31,4	19	31,6	43	32,5	14	33,3	21	34,0	15	34,4	6	33,9	12	33,8	7	32,5	5	31,7	16	31,7	15
,,	0514	30,5	33	31,3	16	31,5	18	32,5	16	33,6	24	34,4	28	34,2	9	34,2	20	34,1	16	33,9	1	31,7	15	31,4	11
,,	0607	31,6	5	31,5	2	31,7	4	31,8	1	32,5	1	32,4	2	32,7	2	33,5	1	33,3	2	33,0	2	31,3	4	31,6	2
,,	0608	31,4	49	31,3	25	31,2	36	32,0	36	32,1	32	32,6	35	33,2	36	33,5	34	33,1	33	32,6	30	31,3	56	31,5	42
,,	0609	31,8	48	31,8	51	31,7	43	31,9	38	32,2	39	32,7	38	33,4	31	33,7	31	33,3	41	33,0	44	31,6	43	31,8	35
,,	0610	31,7	61	31,6	67	31,6	58	31,9	47	32,1	44	32,8	56	33,5	44	33,7	38	33,6	49	33,2	45	31,7	49	31,9	47
,,	0611	32,2	57	32,3	71	31,6	57	32,0	41	32,5	37	33,4	23	33,7	20	33,7	38	33,8	48	33,6	46	32,0	40	32,3	50
,,	0612	31,9	64	31,9	62	31,8	46	31,9	40	32,8	58	33,5	39	33,9	29	33,9	37	33,8	48	33,3	27	31,7	45	32,0	53
,,	0613	32,0	37	31,9	46	31,8	33	32,5	30	33,4	39	34,0	43	34,3	22	34,0	15	33,7	28	33,3	9	31,8	38	32,0	31
,,	0614	31,7	15	31,3	19	31,9	15	32,8	11	33,5	25	34,1	19	34,2	12	34,1	11	33,8	15	33,1	8	32,0	20	31,9	18
1954	0505	32,2	3	32,4	10	32,3	7	32,3	10	32,1	21	32,0	5	32,6	4	32,9	4	33,2	2	33,1	2	32,8	5	30,3	2
,,	0506	31,6	26	32,7	19	32,1	30	32,0	24	31,7	32	31,9	23	32,6	6	32,6	24	32,5	29	32,0	17	31,4	32	30,8	26
,,	0507	31,7	24	31,9	24	32,0	41	32,0	16	31,9	18	31,9	29	32,2	20	32,8	20	33,1	12	32,2	11	31,6	23	31,8	17

„	0508	31,9	9	32,2	16	32,4	7	32,2	5	31,7	5	32,2	9	32,5	8	33,0	4	33,0	8	31,6	7	32,1	11	31,2	8
„	0509	31,8	3	32,2	5	32,4	5	32,0	3	31,8	3	32,8	6	33,3	4	32,4	4	32,3	6	—	—	32,1	8	31,2	5
„	0510	31,9	2	32,3	7	32,3	4	—	—	33,4	2	33,4	6	—	—	31,9	3	32,2	1	31,9	2	32,0	4	31,5	8
„	0511	31,1	9	31,9	1	31,6	4	31,6	1	32,7	2	33,5	8	33,6	5	33,0	3	32,4	3	32,1	10	32,1	4	31,6	6
„	0512	32,0	2	31,6	4	31,2	2	—	—	33,6	1	33,5	3	34,5	3	—	—	32,7	3	32,2	2	31,8	4	—	—
„	0513	31,1	3	31,8	4	31,0	4	32,4	1	33,6	2	34,0	2	34,0	1	34,3	2	32,3	5	32,1	1	32,2	7	32,0	6
„	0514	31,4	1	31,5	6	31,3	10	32,5	3	33,4	3	33,8	7	34,4	5	34,3	6	32,7	7	32,1	4	32,0	6	31,9	1
„	0607	32,4	3	32,2	1	32,1	2	—	—	32,5	1	—	—	33,5	1	31,6	1	—	—	—	—	30,9	1	32,1	1
„	0608	32,1	23	32,1	15	32,1	27	31,8	13	31,9	14	31,8	16	32,4	19	32,9	20	33,1	11	32,0	10	32,2	52	31,6	29
„	0609	32,2	22	31,9	21	32,1	27	31,9	16	31,8	14	32,0	22	32,3	11	33,2	16	33,9	14	32,5	6	32,3	39	31,4	27
„	0610	32,1	29	32,2	20	32,0	29	31,5	21	31,8	21	32,6	25	32,9	14	32,9	21	32,8	16	32,3	9	32,4	37	31,3	27
„	0611	32,5	35	32,4	22	31,7	23	31,6	20	32,3	16	33,2	19	33,5	15	33,0	11	33,3	28	32,7	9	32,7	45	31,8	31
„	0612	32,3	29	32,1	28	31,6	22	31,2	12	32,1	16	33,2	20	33,8	14	33,6	21	33,2	19	32,4	13	32,6	26	31,8	33
„	0613	32,3	12	32,1	16	31,5	16	32,8	10	33,1	9	33,7	16	34,2	10	33,8	15	33,5	6	32,5	7	32,7	11	32,2	7
„	0614	32,2	9	31,8	6	31,1	12	33,1	7	33,4	3	34,1	7	34,3	2	33,9	3	33,7	5	32,4	7	32,4	7	32,2	4
1955	0505	30,6	3	31,8	3	32,7	5	—	—	31,9	6	—	—	31,6	3	31,9	2	33,2	1	32,3	2	31,0	4	31,0	2
„	0506	31,0	27	31,7	17	32,1	34	33,4	19	31,7	19	31,2	14	31,5	13	31,9	13	32,6	8	31,1	15	30,7	28	30,6	28
„	0507	31,1	16	31,4	13	31,5	19	31,7	10	31,7	19	31,3	19	31,7	12	31,7	21	31,6	18	31,5	16	31,1	14	30,7	16
„	0508	31,9	4	32,2	11	31,7	6	31,9	9	31,5	10	31,5	6	31,8	7	31,9	7	32,3	6	32,4	5	31,3	10	30,8	3
„	0509	31,4	1	32,3	7	31,3	1	32,5	5	31,2	5	31,7	8	32,5	2	32,3	9	31,7	4	32,3	4	31,1	12	31,4	5
„	0510	31,8	2	32,5	2	32,1	3	32,2	4	31,2	5	32,3	6	31,4	2	32,5	3	31,7	1	31,8	2	31,7	7	31,7	2
„	0511	32,1	12	32,3	5	32,5	2	32,2	2	31,6	7	32,2	3	32,5	3	32,6	8	31,6	7	31,9	2	31,8	10	31,5	2
„	0512	32,2	2	31,3	1	31,9	3	32,0	2	31,8	4	32,4	2	33,2	1	33,1	1	31,6	3	32,1	1	32,0	1	31,7	1
„	0513	—	—	31,6	1	30,3	1	31,1	1	—	—	32,6	1	33,4	1	—	—	31,9	1	31,8	1	—	—	—	—
„	0514	—	—	—	—	30,4	4	31,5	2	32,6	1	32,7	4	33,6	1	33,9	2	31,5	5	32,6	2	—	—	—	—
„	0607	32,6	1	—	—	—	—	—	—	—	—	31,8	1	—	—	—	—	32,6	1	32,2	1	31,2	1	31,8	1
„	0608	32,2	16	31,4	14	31,3	13	31,9	8	31,8	16	31,5	14	31,7	10	31,6	21	31,6	9	31,8	11	31,6	11	31,7	11
„	0609	32,2	16	31,7	12	31,8	12	31,8	7	31,7	11	31,8	19	31,8	11	31,9	32	31,9	14	32,1	6	31,6	16	31,9	10
„	0610	32,0	16	31,8	18	31,6	10	32,0	9	31,7	13	31,9	19	31,8	11	32,0	20	31,6	13	32,1	9	30,8	17	31,2	9
„	0611	32,3	20	31,8	14	31,1	9	31,7	13	31,7	13	32,1	19	32,4	13	32,9	17	32,5	17	31,9	10	31,6	17	32,3	6
„	0612	31,7	24	31,4	17	31,4	13	31,7	7	31,8	11	32,1	11	33,3	12	33,0	19	32,3	11	32,0	6	31,4	17	32,0	8
„	0613	32,0	9	31,4	5	31,4	10	31,9	11	31,8	5	33,0	7	33,6	10	33,1	12	32,4	13	32,0	6	32,5	4	32,2	6
„	0614	32,0	8	31,3	4	31,4	6	31,8	5	33,1	5	32,9	4	33,8	9	33,5	8	32,3	5	31,9	5	31,9	1	32,2	5

THE SUBTROPICAL LOWER WATER BETWEEN THE PHILIPPINES AND IRIAN (NEW GUINEA).

(Comparative considerations of the results of three expeditions)

by

KLAUS WYRTKI

SUMMARY:

Oceanographic observations are published, taken by the research vessel Siboela in 1949 at 57 stations in the Celebes Sea and around Halmahera. Basing on these observations, an analysis is made of the Subtropical Lower Water (salinity-Maximum) in this region and is compared with the observations of the Snellius and the Dana in 1929. The distribution of the oxygen content allows a distinction of the Lower Water into a northern and a southern water type, which regions of origion are situated in 23 N between 165 E and 165 W and in 15°S between 120° and 150°W respectively. It is shown that the temperature of the salinity maximum in 1949 is 1,4° higher and the salinity 0.11‰ lower than in 1929. The topography of the salinity maximum, which lies in about 100 to 200 m, is closely correlated with the surface currents.

ZUSAMMENFASSUNG:

Ozeanographische Beobachtungen des Forschungsschiffes Siboela aus dem Jahre 1949 an 57 Stationen in der Celebessee und den Gewässern um Halmahera werden veröffentlicht. Auf Grund dieser Beobachtungen wird eine Analyse des Subtropischen Unterwassers (Salzmaximum) durchgeführt und mit den Beobachtungen der Snellius und Dana in diesem Gebiet aus dem Jahre 1929 verglichen. Die Verteilung des Sauerstoffgehaltes ermöglicht eine Unterteilung des Unterwassers in eine nördliche und eine südliche Wasserart, deren Entstehungsgebiete in 23°N zwischen 165°E und 165 W und in 15 S zwischen 120 und 150 W liegen. Es wird gezeigt, dass die Temperaturen im Salzmaximum im Jahre 1949 um 1,4° höher und der Salzgehalt um 0.11 ‰ niedriger sind als 1929. Die Topographie des Salzmaximums, das in etwa 100 bis 200 m liegt, steht in enger Beziehung zu den Strömungen an der Oberfläche.

ICHTISAR:

Penjelidikan mengenai oceanografi jang diselenggarakan oleh kapal penjelidikan laut dalam tahun 1949 di-57 setasion di laut Sulawesi dan disekitar Halmahera, telah diumumkan.

Berdasarkan penjelidikan ini, dibikinlah suatu analisa dari lapisan air laut subtropis (maksimum kadar garam) didaerah ini dan dibandingkan dengan penjelidikan² dari Snellius dan Dana dalam tahun 1929. Keadaan kadar zat pembakar memungkinkan suatu perbedaan dari lapisan air laut mendjadi djenis air daerah Utara dan daerah Selatan, daerah-daerahmana masing-masing asalnja berada di 23° L.U. antara 165° B.T. dan 165° B.B. dan di-15° L.S. antara 120° dan 150° B.B. Telah diperlihatkan, bahwa suhu dari maksimum kadar garam dalam tahun 1949 adalah 1,4° lebih tinggi dan kadar garamnja 0,11‰ lebih rendah daripada dalam tahun 1929. Topografi dari maksimum kadar garam jang berada diantara l.k. 100 dan 200 m. saling mempengaruhi erat sekali dengan arus dipermukaan.

In large areas of the tropical oceans a salinity maximum is situated shortly below the surface layer. At high temperatures it lies in the upper limit of the tropical discontinuity layer in a depth between 50 and 150 m. The area of origin of this watermass of high temperature and salinity is to be found in the region of high excess of evaporation over precipitation in about 20°N and 20°S. Here at its origin this watermass sinks and spreads towards the equator, accordingly to its density, at the upper limit of the discontinuity layer. As a result of its origin and spreading, this watermass is called the Subtropical Lower Water. In the Atlantic Ocean this phenomenon has been described by DEFANT (1936) when discussing the results of the Meteor-Expedition. In the Pacific Ocean a corresponding investigation is lacking, although this phenomenon seems to be more far-reaching there.

The position of the Subtropical Lower Water implies that it will be transported with the currents of the surface layer. It penetrates also with these currents into the smaller adjacent seas, so from the Pacific Ocean into Indonesian waters. A chart of the salinity distribution in 150 m depth in the Indonesian Archipelago, drawn by VAN RIEL (1938) from the observations of the Snellius-Expedition shows how far this process reaches.

In 1949 the Laboratorium Penjelidikan Laut in Djakarta has made serial observations in the Celebes Sea and in the adjoining parts of the

Pacific Ocean with the research ship "Siboela". These observations permit following the penetration of the Lower Water into the Indonesian waters between the Philippines and Irian (New Guinea). Also a comparison is possible between these observations and those of the Snellius and the Dana, which have made numerous oceanographical stations in this area in 1929 and 1930.

The observations. The area of this investigation includes the Celebes Sea and the western part of the Pacific Ocean south of 7°N and west of 140°E. In the Indonesian Archipelago the northern part of the Strait of Macassar and the region between Celebes and Irian are included (Fig. 1). In this area 96 stations of the Snellius (VAN RIEL, 1950) for the years 1929 and 1930 are available. Their positions are selected to be over the greatest depths, the trenches and the saddles, according to the character of this expedition as a deep sea expedition. Lesser regard has been taken to the conditions in the upper layers. Furthermore, the stations do not reach over the line Philippines -Irian into the Pacific Ocean.

The Dana has also taken oceanographic observations in this region at 26 stations in 1929 (THOMSEN, 1937). Some of these stations are situated in the western Pacific Ocean north of Irian and form a good supplement to the Snellius observations. Both expeditions have determined temperature, salinity and oxygen with small intervalls in depth and the accuracy of the observations satisfies all requirements of modern oceanographic investigations.

In contrast to these deep sea expeditions, the "Siboela" made measurements only down to 250 m, and did not determine the oxygen-content. Because the investigations, were limited to the upper layers, the 57 stations could be uniformly distributed. The distance selected was 60 sm. The stations are situated in the southern part of the Celebes Sea, around the island Halmahera, and reach north of Irian up to 134°E (Fig. 1). The observations have been made under the command of Mr. P. CH. VEEN, at this time oceanographer at the Laboratorium Penjelidikan Laut.

The observations taken at 57 stations have been worked up and are presented in the appendix. As far as obtainable from the protocols the temperatures were not corrected and therefore are reproduced only to 0.1° Centigrade. The accuracy of the salinity determination is about 0.04‰, which is insufficient for interpretation of deep sea observations.

However, for a treatment of the conditions in the upper 200 m with their relatively large fluctuations, this error might be permissible. Ac-

Fig. 1. Station chart.

cordingly, the author has resolved to use the observations and to publish them in the appendix. Single observations must be corrected when drawing the TS-correlations of the stations; the interpolated values are marked in the tables. Not well closed water bottles seem to be the reason in all cases, because the salinities show the values of the water at the surface.

Complementary to these observations every two stations of the Planet (BRENNECKE, 1909) and of the Albatros (BRUNEAU a.o., 1948) in this region have been used.

If a large number of stations is available in such a small region, it is of interest to combine stations of the same season, to get a picture of the fluctuations during the year. In this case it is not possible, because nearly all stations fall into the period between May and October, as shown in table 1.

TABLE 1. DISTRIBUTION OF THE STATIONS ON THE DIFFERENT MONTHS.

Ship	J	F	M	A	M	J	J	A	S	O	N	D	sum
Snellius	—	—	—	—	19	19	2	14	27	15	—	—	96
Dana	—	—	2	2	—	1	11	10	—	—	—	—	26
Siboela	—	—	—	—	—	—	—	35	22	—	—	—	57
Planet / Albatros	3	—	—	—	—	—	—	—	1	—	—	—	4

On the other hand, it might be possible to compare the distribution of the properties at the same season, but for different years. So the observations of the Dana in July/August 1929, together with those of the Snellius in August September 1929, give a quasi-synoptic picture to compare with the observations of the Siboela in August/September 1949, 20 years later. For a third presentation, the observations of the Snellius from May/June 1930 can be used, which cover the area between Mindanao and Halmahera with relatively close observations.

The vertical distribution of properties. A selection of four stations from different parts of the area of investigation may give an impression of the vertical distribution of temperature, salinity, oxygen and density (Fig. 2). Station Da 3754 lies north of Irian in the region of the South Equatorial Current, which shows its strongest development in this season. The homogenous surface layer reaches to 75 m. Immediately below it the transition to the Lower Water takes place in a layer only 25 m thick. The Lower Water itself has a vertical extention of 100 m, in which the salinity

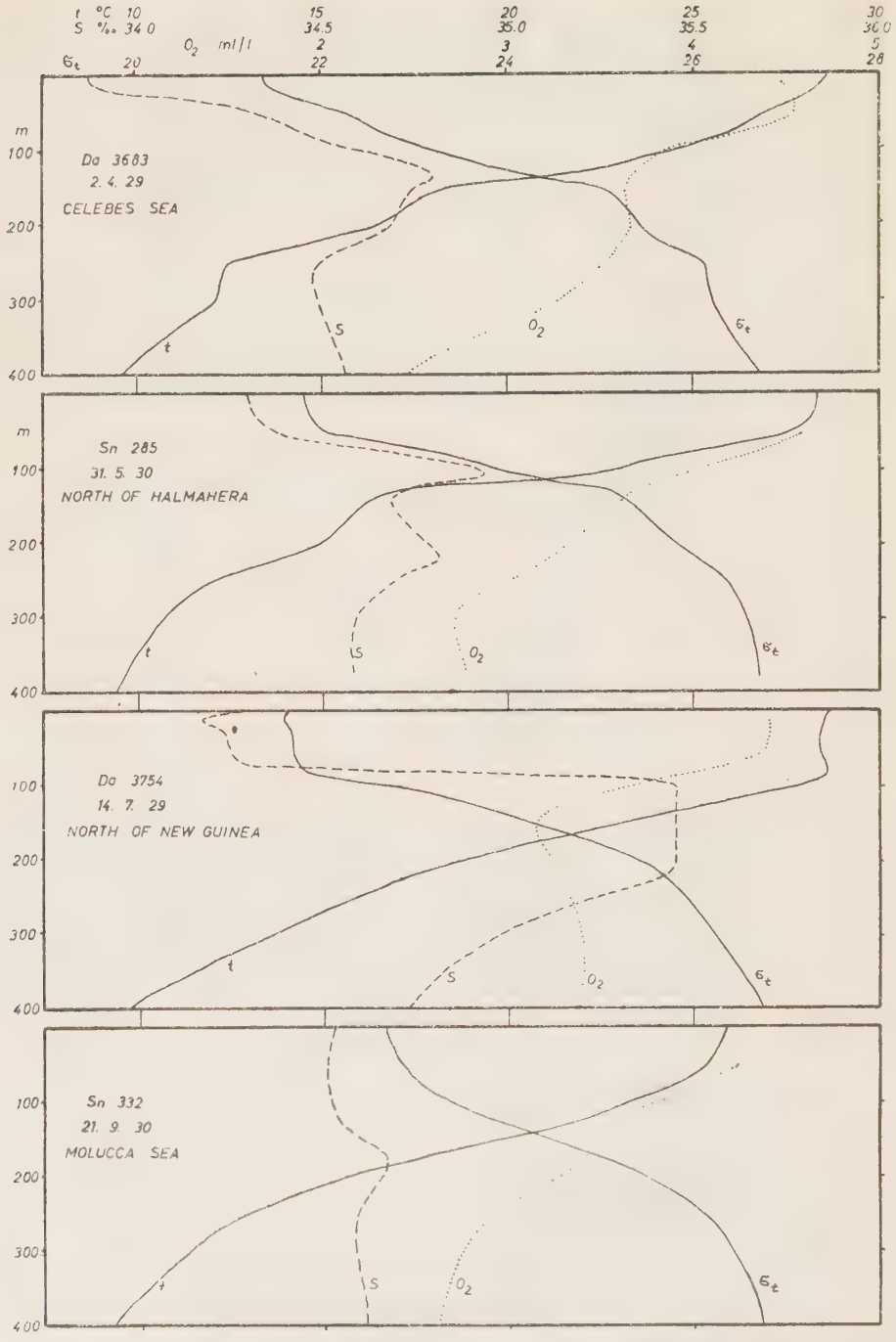

Fig. 2. Vertical distribution of temperature, salinity density and oxygen-content at four selected stations. The positions of the stations are given in Fig. 1.

is homogenous, while the temperature decreases from 27° to 19°. The distribution of density shows the Lower Water occupying the upper half of the discontinuity layer; in the lower half a gradual transition to the Intermediate Water takes place. That implies, that the Lower Water in fact follows the movement of the surface layer, because the boundary of movements lies in the lower parts of the discontinuity layer, as theoretical investigations of ROSSBY (1951) have shown. Within the Lower Water a small oxygen minimum is found.

About in the centre of the Celebes Sea the station Da 3683 is placed. Here a continuous transition from the waters of the surface to the Lower Water is noted produced by the mixing processes. The salinity in its maximum is 34,8‰, significantly less than the waters north of Irian with 35,5‰. Remarkable is the coincidence of the salinity maximum with the strongest density gradient in 135 m. An oxygen minimum is also indicated, although usually not found in the Celebes Sea. It might be more convenient to speak there from a layer of constant oxygen content, which lies shortly below the salinity maximum. The Intermediate Water is to be found at this station in about 270 m with salinities below 34,5‰.

A completely new phenomenon of a double salinity maximum is shown at station Sn 285, situated at the entrance of the Celebes Sea north of Halmahera. This will later enable us to separate two water types in this region, which indicate two different regions of origin. But some conjectures may be made here. In the Celebes Sea (Da 3683) the salinity maximum has, with 3.65 cm^3/l, a higher oxygen content than north of Irian (Da 3754), where it is only 3.30 cm^3/l at a higher salinity.

That implies that the Lower Water in the Celebes Sea can not be derived by mixing from the water north of Irian because, in that case, salinity and oxygen would decrease simultaneously. Therefore two different water types with different regions of origin must exist, and the station Sn 285 must lie in the boundary zone of both water masses, which overlap here according to their density. Also, the difference in oxygen is clearly distinguished between both salinity maxima, which is 3.9 in the upper and 3.2 cm^3/l in the lower maximum.

In the Molucca Sea, southwest of Halmahera, where station Sn 332 is situated, the Lower Water is seen only in its last branch. The salinity in the maximum differs only 0.1‰ from those of the waters above and below the maximum, which lies below the middle of the discontinuity layer. A small deflection of the oxygen curve is noted near the salinity maximum.

The stations here presented show the variety of the hydrographic conditions and give a review over the situations in the region. They are selected from the whole material as representative of the respective regions. For further consideration the TS and TO_2 diagrams have been drawn for every station as well as the vertical curves of the properties. From these the temperature, the salinity, the oxygen content, the density and the depth of the salinity maximum could be obtained.

The horizontal distribution of properties in the salinity maximum. Charts of the distribution of the hydrographic factors have been drawn by means of the values obtained from the vertical curves. Here only three charts of the distribution of the salinity in its maximum and one chart of the distribution of oxygen in the salinity maximum are represented. Fig. 3 gives the chart of the salinity in its maximum for the period July/September 1929, drawn from Snellius and Dana stations. In the region north of Irian and east of Halmahera the salinity maximum has a relatively uniform salinity of 35.4‰. It extends to the west in a belt along the north coast of Irian, where salinities up to 35.6‰ are found and is deflected to the north off the east coast of Halmahera. To the north the salinity decreases slowly to 35.2‰. South of Mindanao a tongue with salinities above 34.9‰ extends to the center of the Celebes Sea. A discontinuity with a decrease of salinity from 35.4 to 34.9‰ reaches from Halmahera to the north. Between Halmahera and Irian the Lower Water also penetrates to the south with decreasing salinities.

The salinity in its maximum according to the results of the Siboela in August/September 1949 is drawn in Fig. 4, and shows a similar distribution. The South Equatorial Current also extends along the north coast of Irian to the west and is deflected to the north off Halmahera, where the salinity slowly decreases. Remarkable is the area of salinity below 35.0‰ northeast of Halmahera. Here a large eddy is situated, as later will be shown, in which the South Equatorial Current is turning to the Counter Current. The discontinuity north of Halmahera also is noted, but is not developed as sharply as in 1929. A tongue of higher salinity (34.7‰) this time does not reach to the center of the Celebes Sea, but to the north east corner of the island. In general the salinity is about 0.1 to 0.2‰ below that in 1929.

The third chart gives the distribution of the salinity in its maximum according to the results of the Snellius in May/June 1930, in the region between Halmahera and Mindanao, and in September/October 1930 in the region around Halmahera (Fig. 5). The higher density of stations in

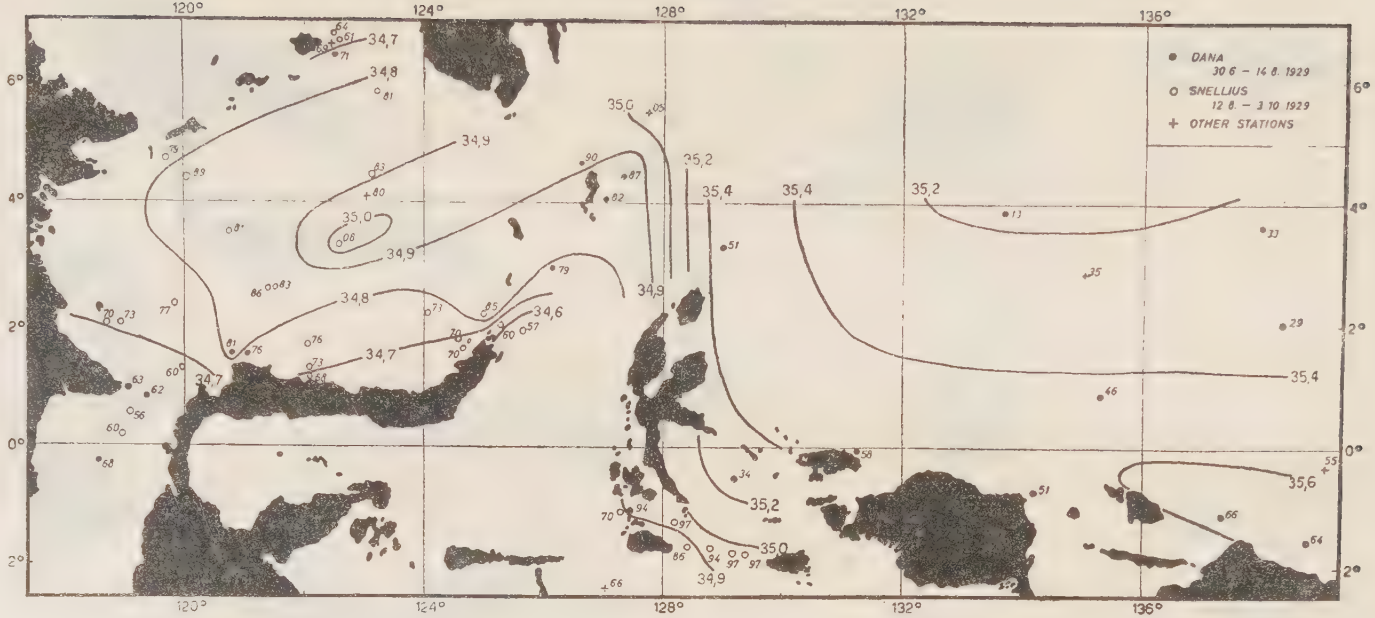

Fig. 3. Salinity in the salinity-maximum, July/September 1929.

Fig. 4. Salinity in the salinity-maximum, August/September 1949.

Fig. 5. Salinity in the salinity-maximum, May/July and September/October 1930.

this chart shows that the discontinuity north of Halmahera is split and is developed weakerly in this season. This is in accordance with the current conditions, as described by SCHOTT (1939), which shows the South Equatorial Current not developed in this region at this season. South of Mindanao relatively high saline waters (34.8‰) penetrate to the central parts of the Celebes Sea.

The chart of the oxygen distribution in the salinity maximum is drawn from all available observations, without regard to season. This presentation shows some remarkable characteristics having an essential meaning for the further investigations. The area north of Irian has a very uniform oxygen content with values between 3.2 to 3.4 cm^3/l. Contrary to this, in the Celebes Sea an essentially higher oxygen content between 3.6 to 3.9 cm^3/l is found. Clearly also, the discontinuity north of Halmahera is developed in the oxygen content, which increases from 3.3 to 4.0 cm^3/l. The area of high oxygen south of Mindanao indicates that the Lower Water in the Celebes Sea is supplied from this source.

The distribution of temperature and density in the salinity maximum does not give such an uniform picture, because the maximum is met at higher or lower temperatures, according to the mixing processes with the waters above or below the maximum, depending on which is the stronger. The variation of the temperature is the controlling factor for the variation of the density, because the variations of salinity are comparable small. Therefore the charts of the distribution of these properties are not presented. The magnitude of those variations can be seen from the scattering of points in the TS diagram (Fig. 8). Temperatures vary between 25° and 17°, densities between 23.5 and 25.5 is the salinity maximum.

The origin of the water types. The envelopes, drawn from the TS diagrams of the three expeditions are given in Fig. 7. They show clearly that at least three water types take part in the mixing processes. These are the warm, low saline water with temperatures above 25° and salinities below 34‰, forming the surface layer. In the depths the Intermediate Water is spreading with low temperatures and salinities of about 34.5‰. Clearly two different Intermediate Waters are distinguished, the northern with 10° is warmer than the southern with 6°. These waters lie in the region north of Irian in about 300 and 800 m depth, respectively, and form there a salinity minimum. The Subtropical Lower Water with high temperature above 26° and high salinities above 36‰ forms the salinity maximum between 100 and 200 m. Later also this water type will be subdivided by means of its oxygen content. By the mixing processes the TS

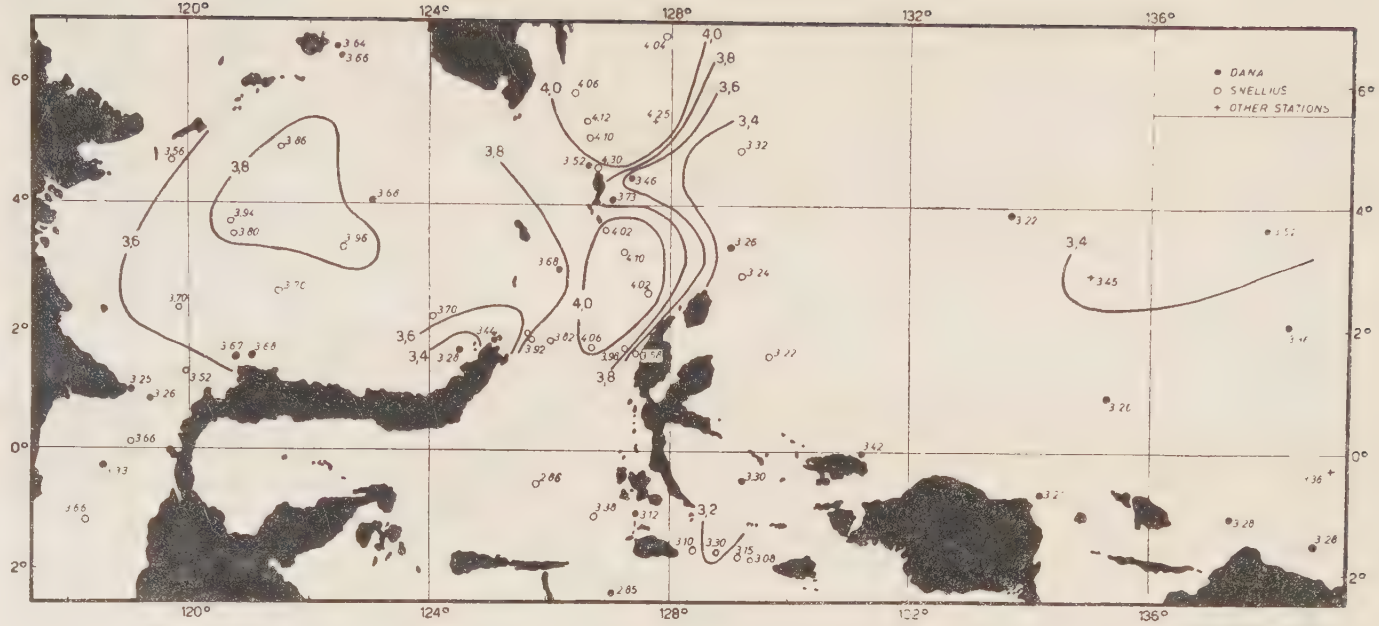

Fig. 6. Oxygen-content in the salinity-maximum.

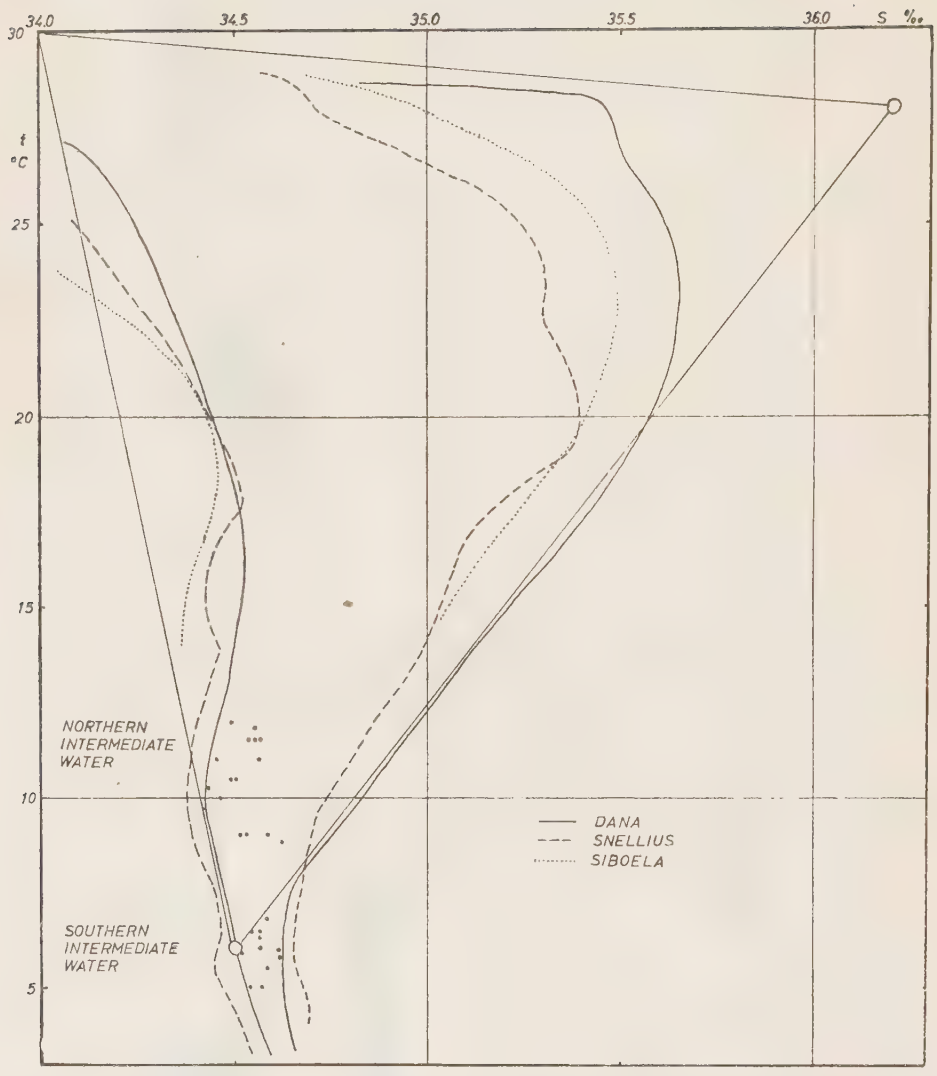

Fig. 7. Envelopes of the TS-curves of the stations of the three expeditions and TS-relation in the northern and southern Intermediate Water according to Dana stations.

values in the salinity maximum deviate more and more from these properties in the region of origin. This is demonstrated by the different recesses of the envelopes towards high salinities according to the extension of the station net of the three expeditions to the east. As mentioned

above, the oxygen content in the salinity maximum is higher in the Celebes Sea than in the region north of Irian. The Lower Water there cannot come from the region of the South Equatorial current. Furthermore, the discontinuity in the salinity and in the oxygen north of Halmahera indicates a boundary there. To come to an analysis of this pattern, the values of temperature, salinity and oxygen in the salinity maximum for all stations with oxygen observations were combined to a TS and a SO_2 diagram (Fig. 8). The SO_2 diagram shows two different clouds of points, one with only a small increase of oxygen content with increasing salinity, representing the southern Lower Water, the other with a rapid increase in oxygen content with the salinity, the northern Lower Water, which reaches far higher values of oxygen. Transfering this subdivision to the TS diagram, one notes also there a subdivision, which is not distinguishable from the TS diagram alone. In general, the southern Lower Water has a higher salinity and a lower oxygen content. Also the stations Sn 83-86, situated southeast of Halmahera, can be identified very clearly by means of the SO_2 diagram as belonging to the southern Lower Water, although their TS values are falling into the range of the northern Lower Water.

Envelopes have been drawn for both Lower Waters from the TS diagrams of all stations, which could be identified by the SO_2 as belonging to the northern or southern Lower Water. These are shown in Fig. 9. It can be seen, that both planes partially overlap within which limits points from the southern, as well as from the northern Lower Water can lie. The subdivision according to this diagram is therefore not clear, but it is always possible to make such divisions, if oxygen values are available. Now all stations without oxygen observations were distributed by means of this diagram to one or the other Lower Water. The geographical position of the both Lower Waters in their boundary area is given in Fig. 10. The line of demarkation (full line) runs from Halmahera to the north and to the south and falls together with the discontinuity in salinity and oxygen, visible in Fig. 3-6. In parts of the area there is a double salinity maximum, as shown in Fig. 10. This second maximum in any case belongs to the southern Lower Water, as the TS values, drawn in Fig. 9 show. In the region of the double salinity maximum, northern Lower Water lies above the southern Lower Water. The extension of the southern Lower Water to the west is indicated by the broken line. The origin of this feature will be discussed later.

For an identification of the regions of origin of both water types, the TS correlation at the surface of the Pacific Ocean has been inves-

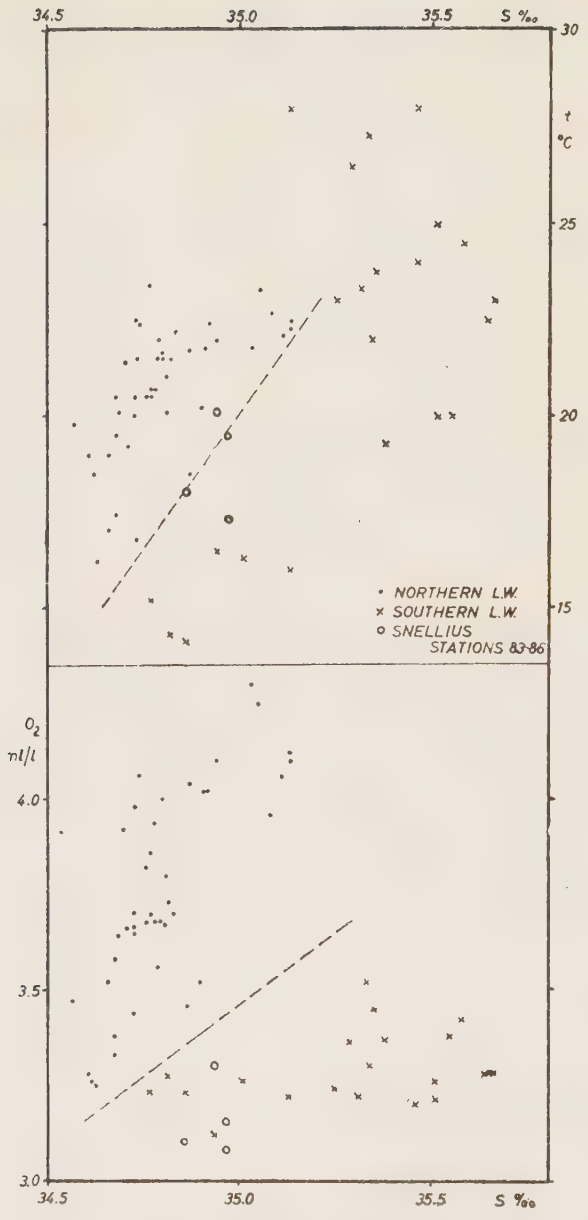

Fig. 8. TS and SO_2 values in the salinity-maximum for all stations with oxygen observations.

tigated. Therefore the charts of the average surface salinity and the seasonal charts of surface temperatures were used, as drawn by SCHOTT (1935). Presentations of the annual variation of surface salinity in the Pacific Ocean are not yet available. The investigation of the TS correlation shows that at the time of the temperature maximum in the regions of the salinity maxima can suitable TS values be found which explain the

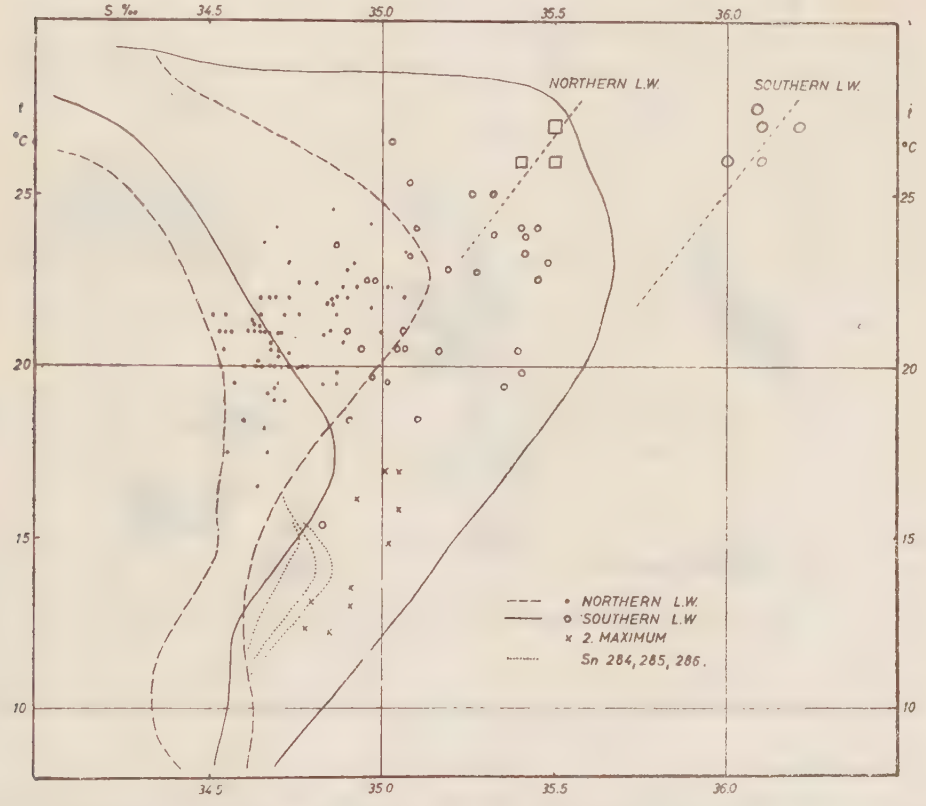

Fig. 9. Envelopes of the TS relations for the northern and southern Lower Water and TS values in the regions of origin of both water types.

origin of the Lower Waters. These values, which must lie at high temperature in the elongation of the branch of the envelopes running from the Intermediate to the Lower Water, are introduced in Fig. 9.

The salinity at the surface of the Pacific Ocean, according to SCHOTT (1935), is partly redrawn in Fig. 11. In this figure the regions are introduced with broken lines, in which suitable TS combinations occur, for the origin of the Lower Waters. These lie for the northern Lower Water in

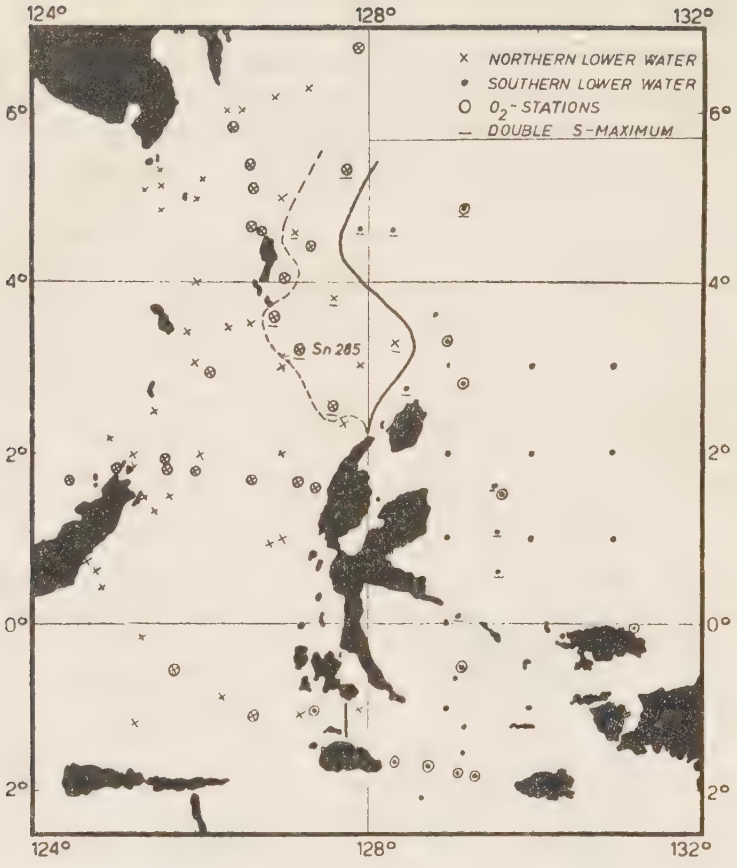

Fig. 10. Chart af the boundary of both Lower Waters and stations with a double salinity maximum.

about 25°N between 165°E and 165°W in August at a salinity of 35.5‰ and at temperatures up to 27°. The region of origin of the southern Lower Water lies in about 18°S between 120° and 150° W in February at a salinity of 36.2‰ and a temperature of 27°. The corresponding TS values are introduced into Fig. 9. Remarkable is the more eastern position of the southern region of origin and its higher salinity. Both regions fall together with a line of convergence (Fig. 11, dotted line), which can easily be seen in the current charts of the corresponding months. It is remarkable how far reaching is the extension of the Lower Waters formed at both these places which can be seen especially from Fig. 11. The properties

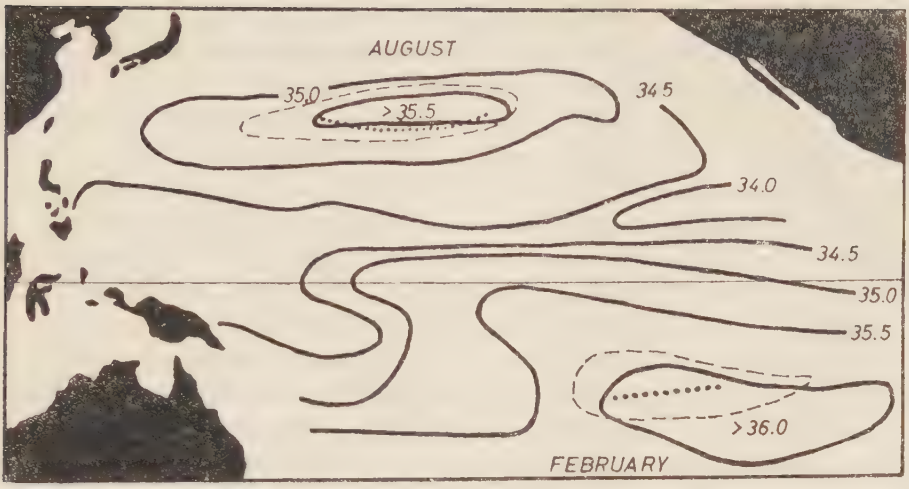

Fig. 11. Surface salinity in the Pacific Ocean after SCHOTT and regions of origin of both Lower Waters (broken line) and lines of convergence (dotted line).

of the water types which take part in the mixing processes in the region between the Philippines and Irian are summerized below:

Water type	temperature	salinity	remarks
Tropical surface water	> 27	< 34.5	low density
Northern Lower Water	26.5	35.5	100 - 150 m
Southern Lower Water	27	36.2	125 - 175 m
Northern Intermediate Water	10	34.5	300 m
Southern Intermediate Water	6	34.5	800 m

The double salinity maximum and the annual variation. In the region north and east of Halmahera at a number of stations a double salinity maximum is observed, but from Fig. 10 it can be seen that this feature has no uniform character, because between the stations with a double maximum one will always find stations with one maximum. Investigation leads to the conclusion that it must be the result of the annual variations. For such a comprehensive investigation of the annual variation not enough stations are available during the period November-April, as mentioned in the beginning.

To fill this lack it seems necessary to draw the attention to the general circulation in this region, as presented by SCHOTT (1939). He gives the surface currents in this region for summer and winter, that is

the times of the strongest and weakest development of the South Equatorial Current. During the period June/September, wherein nearly all our observations fall, the South Equatorial Current flows with high velocities to the west along the northern coast of Irian. Off the coast of Halmahera it is deflected to the north, where it joints with the waters coming between Halmahera and Celebes from the Molucca Sea, and thence passes over into the Counter Current after being deflected further to the east. The Mindanao Current, resulting from the North Equatorial Current, is developed only weakly. It splits southeast of Mindanao, one branch going to the Celebes Sea, the other to the east into the Counter Current.

One finds a completely contrary development during the period December/March when the North Equatorial Current shows its strongest development. This leads also to a strong development of the Mindanao Current, which only partially enters the Celebes Sea. The greater part is deflected to the east into the Counter Current. In the region north of Irian only weak and irregular drift currents are found. Only east of 140°E can the South Equatorial Current be noted.

This description shows that the region north and east of Halmahera will be filled in the annual cycle alternately with watermasses of the North and of the South Equatorial Currents. To give a picture of the variation of the vertical distribution of temperature and salinity the TS curves of five stations in this region are drawn (Fig. 12), which positions are introduced into Fig. 1. It is clearly noted that in July the station Da 3745 belongs to the southern Lower Water, while in January the station A 162 belongs to the northern Lower Water. It is during the times between these that the exchange of watermasses must occur. The manner in which this occurs is shown by the stations Sn 269 and Sn 285 in May. The distribution existent in January is attacked from below, whereby the southern Lower Water moves underneath the northern. In this process the double maximum is formed, which is conditioned dynamically. This process of undersliding lasts as long as the whole water column is occupied by the southern Lower Water, and the conditions of the station Da 3745 are produced. The alternate process which occurs between September and January can be shown by means of the Japanese station 31/35 in December 1934. During this time the southern Lower Water is attacked from above by water masses of the northern Lower Water, so that its salinity maximum comes to lie always at lower temperatures, up to the time it is completely removed.

East of Halmahera a temporary double salinity maximum is found which seems also to be conditioned dynamically. Yet both maxima belong

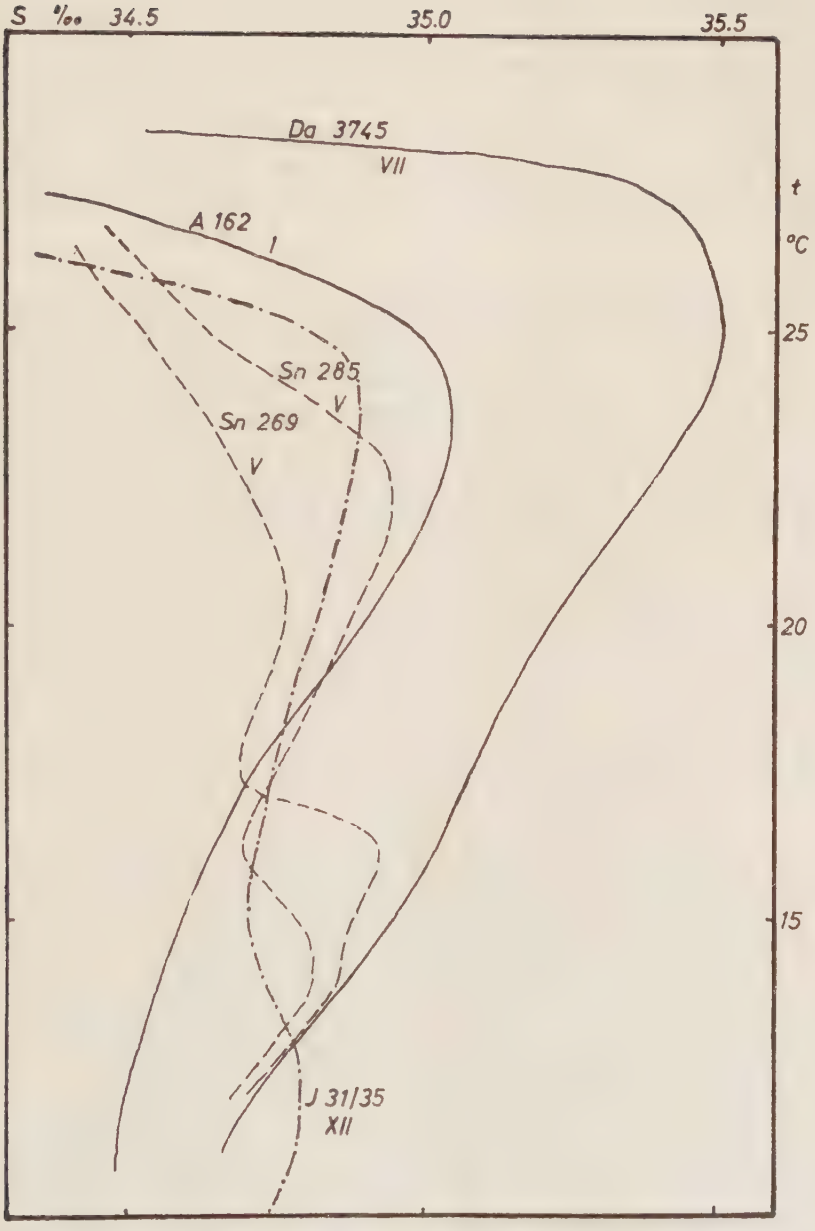

Fig. 12. TS relations of stations in the area of the double salinity maximum, demonstrating the annual change of water masses.

to the southern Lower Water. This second maximum seems to originate every year with the advancing of the South Equatorial Current if new Lower Water enters this region and replaces the Lower Water of the last year. Both double salinity maxima are reduced very simply to dynamical processes at the exchange of water masses. By this sample one notes the big influence of the variations of the circulation at the surface on the hydrographic conditions below the surface, which reaches deep into the discontinuity layer.

Longterm fluctuations. During the discussion of the horizontal distribution of the salinity in the salinity maximum it was noted that in August/September 1949 the salinity was higher than in July/September 1929 (Figs. 3, 4). For a further investigation of this fact the differences in salinity and temperature between TS values in the salinity maximum were calculated for neighbouring stations of both years. These 23 stations do not differ more then one month in time, so that an effect of the annual variation may be disregarded. The difference between the values of 1949 and these of 1929 are given in Fig. 13. The points show considerable scatter, but lie clearly at higher temperatures and lower salinities. On the average, the salinity maximum in 1949 has a temperature 2 higher and a salinity 0.11‰ lower than those of 1929. While the causes of these fluctuations cannot be determined from these observations it may be either variations in the properties of the water masses at their formation at the surface, or fluctuations in the strength of the circulation.

The depth of the salinity maximum in relation to the water movements. The depth of the salinity maximum, obtained from the vertical curves of salinity, is presented in Fig. 14. When drawing this chart, the values must be smoothed because of the great vertical fluctuations. These fluctuations of the depth of the maximum within short intervals are produced at first by internal tides and internal waves. The vertical movements of the discontinuity layer are large in this region and amount to 10-40 m, (LEK, 1938) according to the observations of the Snellius.

The depth of the salinity maximum and of the discontinuity layer must be in close connection with the topography of the surface and the currents in the surface layer. Because the observations originate mostly from the period June September, one must compare them with the current charts of the same season. The charts of the surface currents given by SCHOTT (1939) for this region in northern summer are especially suit-

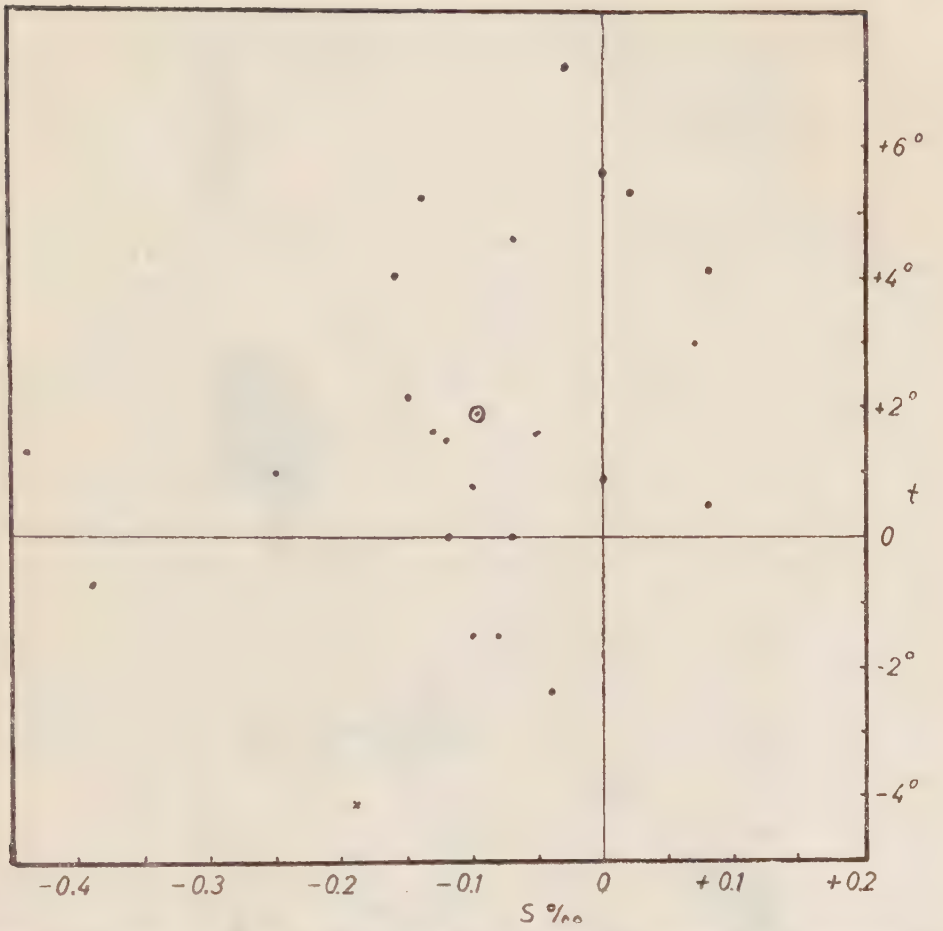

Fig. 13. Difference of the TS values in the salinity maximum of neighbouring stations between 1929 and 1949.

able. The current boundaries, convergences and divergences given by him are introduced into Fig. 14.

The most remarkable feature in the circulation of this region is the large eddy northeast of Halmahera, in which the South Equatorial Current turns into the Counter Current. The end of the line of convergence between both currents given by SCHOTT falles nearly into the centre of this eddy. Furthermore, this presentation shows the South Equatorial Current following the slope when crossing the equator north of Irian, because the deflecting force of the earth's rotation vanishes at the equator. Contrary to this in the region of the Counter Current a considerable cross slope exists.

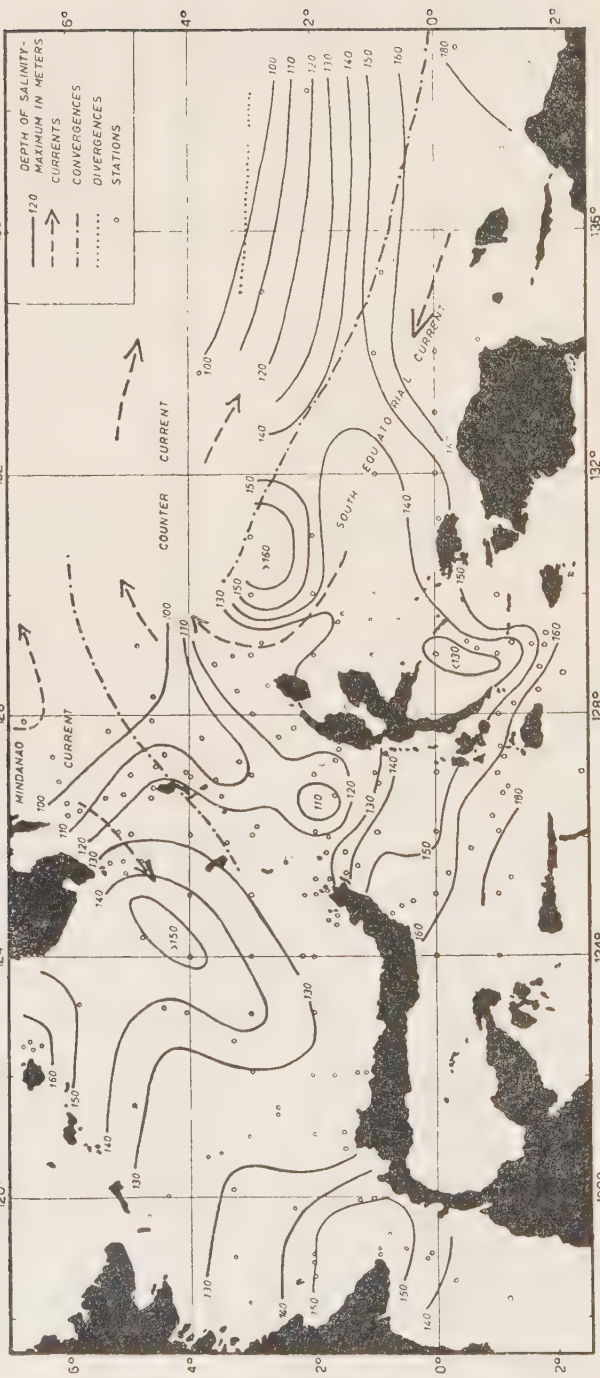

Fig. 14. Topography of the salinity maximum.

According to the chart of SCHOTT, water masses flow to the north between the northeast corner of Celebes and the island Halmahera, joining with the Counter Current. These water masses also follow the slope when crossing the equator, but a cross slope is noted in the course of this flow just at about 4°N.

The Mindanao Current comes from the north and splits southeast of Mindanao into two branches, one of these joining with the Counter Current, the other flowing into the Celebes Sea. Here no clear correlation to the topography of the salinity maximum can be noted. Indeed, the observations of the Snellius in this region are for May only, and in this month the splitting of the Mindanao Current might take place further south, a conclusion drawn from the charts of SCHOTT for the northern winter. One could identify the branch of the Mindanao Current, forming the Counter Current with the 100 m depth line, while one had to associate the branch flowing to the Celebes sea with the 130 m depth line.

In the Celebes Sea Fig. 14 shows a large anticyclonic eddy in its center in about 4°N and 124°E. Contrary to this, the charts of the surface currents (US Hydrographic Office, 1945) show a cyclonic eddy not only in August, but during the whole year in the Celebes Sea. A conclusion in this question can be made only with a knowledge of the current observations used in drawing these charts, or with more extensive observations.

Appendix.

List of oceanographic stations obtained by MS SIBOELA in 1949 in the region north of Irian and in the Celebes Sea.

(m depth of observation; t temperature C°; S salinity $^0/_{00}$; * interpolated values).

Station Si. 1. 13. 8. 1949 01^h 1° OO′ N, 120° OO′ E			Station Si. 2. 13. 8. 1949 11^h 1° OO′ N, 119° OO′ E.			Station Si. 3. 13. 8. 1949 20^h 2° OO′ N, 119 OO′ E.		
m	t	s	m	t	s	m	t	s
0	28,8	33,89	0	28,4	34,02	0	28,4	34,11
10	28,8	33,85	10	28,5	34,01	10	28,4	34,04
20	28,7	33,87	20	28,5	34,03	20	28,3	34,01
30	28,8	33,85	30	28,4	34,06	30	28,3	33,94
50	27,5	34,43	50	28,2	33,97	50	27,6	34,19
75	24,7	34,58	75	27,3	34,22	75	27,4	34,28
100	24,0	34,64*	100	25,7	34,41	82	26,3	34,42*
150	22,2	34,73	150	21,1	34,66	123	26,0	34,47
200	21,3	34,70*	200	19,2	34,60*	164	25,9	34,51
250	17,8	34,54	250	12,7	34,40	205	22,5	34,68

Station Si. 5.
14. 8. 1949 16h
3° OO′ N, 120 OO′ E.

m	t	s
0	29,2	34,04
9	29,0	33,65
18	28,9	33,76
27	28,8	33,69
46	28,6	33,87
68	27,8	34,27
90	23,6	34,66
136	19,2	34,54
152	15,3	34,45
227	12,2	34,40

Station Si. 6.
15. 8. 1949 02h
2° OO′ N, 120° OO′ E.

m	t	s
0	28,5	33,57
10	28,8	33,68
20	28,9	33,81
30	28,9	33,79
50	28,6	33,84
65	28,6	34,19
87	24,8	34,56
130	19,8	34,61
173	17,4	34,53
217	15,0	34,36

Station Si. 7.
15. 8. 1949 13h
2° OO′ N, 121° OO′ E.

m	t	s
0	31,5	33,73
10	29,0	33,85
20	29,0	33,86
30	28,6	34,00
50	28,2	34,21
71	24,3	34,58
94	20,8	34,57
141	17,6	34,58
188	15,9	34,44
235	14,4	34,38

Station Si. 8.
15. 8. 1949 22h
3° OO′ N, 121° OO′ E.

m	t	s
0	28,8	33,83
10	28,8	33,77
20	28,8	33,90
30	28,5	33,90
50	27,7	34,25
76	27,4	34,15
115	26,5	34,52
153	22,4	34,73
192	18,0	34,53

Station Si. 9.
16. 8. 1949 08h
3° OO′ N, 122° OO′ E.

m	t	s
0	28,2	33,95
10	28,7	33,98
20	28,6	33,96
30	28,6	33,94
50	27,1	34,38
71	25,1	34,70
94	23,7	34,74
141	18,6	34,76
188	18,1	34,68
235	14,1	34,39

Station Si. 10
16. 8. 1949 17h
2° OO′ N, 122° OO′ E.

m	t	s
0	29,0	33,88
10	28,9	33,82
20	28,7	34,07
30	28,5	34,10
50	27,8	34,18
73	27,3	34,20
97	24,0	34,65
145	22,4	34,76
193	17,1	34,59
242	14,9	34,52

Station Si. 11.
17. 8. 1949 03h
2° OO′ N, 123° OO′ E.

m	t	s
0	28,7	33,88
10	28,9	33,77
20	28,8	33,87
30	28,7	33,95
50	26,9	34,33
58	24,4	34,49
77	23,1	34,55
115	19,5	34,76
153	15,8	34,56
192	14,5	34,49

Station Si. 12.
17. 8. 1949 12h
3° OO′ N, 123° OO′ E.

m	t	s
0	28,8	39,93
10	28,7	33,85
20	28,7	33,90
30	28,8	33,89
50	28,2	33,99
75	27,1	34,20
100	25,5	34,59
150	16,5	34,51
200	12,3	34,32
250	10,2	34,23

Station Si. 13
18. 8. 1949 00h
2° OO′ N, 124° OO′ E.

m	t	s
0	28,0	39,93
10	28,5	33,86
20	28,6	33,90
30	28,2	33,82
50	28,0	33,87
75	25,1	34,53
100	23,3	34,54
150	19,2	34,63
200	14,9	34,42
250	13,7	34,35

Station Si. 14.
18. 8. 1949 06h
2° OO′ N, 125° OO′ E.

m	t	s
0	27,8	33,88
10	28,5	33,96
20	28,3	33,87
30	28,1	33,87
50	27,2	33,99
75	24,0	34,70
100	22,0	34,66
150	18,5	34,59
200	15,2	34,41
250	12,2	34,37

Station Si. 15.
22. 8. 1949 04h
4° OO′ N, 125° 00′ E.

m	t	s
0	28,1	33,84
10	28,6	33,85
20	28,6	33,85
30	28,6	33,90
48	28,5	33,95
73	27,4	34,36
97	24,4	34,44
145	18,7	34,52
193	15,5	34,51
242	11,8	34,27

Station Si. 16.
22. 8. 1949 14h
4° OO′ N, 124° OO′ E.

m	t	s
0	28,7	33,91
10	29,1	33,90
20	28,8	33,99
30	28,7	33,84
48	28,6	33,93
73	27,1	34,39
97	24,7	34,53
145	19,1	34,56
193	17,0	34,57
242	14,7	34,44

Station Si. 17.
22. 8. 1949 23h
3° OO′ N, 124° OO′ E.

m	t	s
0	28,7	34,07
10	29,1	34,04
20	29,0	33,91
30	28,7	—
50	28,5	—
71	28,1	—
94	25,0	34,64
141	21,8	34,65
188	16,5	34,59
135	13,8	34,36

Station Si. 18.
23. 8. 1949 08h
3° OO′ N, 125° OO′ E.

m	t	s
0	28,7	34,05
10	28,8	34,04
20	28,7	34,05
30	28,7	34,28
44	27,6	34,26
65	25,3	34,43
87	23,7	34,62
130	19,0	34,64
173	16,3	34,57
297	13,3	34,37

Station Si. 19.
24. 8. 1949 06h
3° OO′ N, 126° OO′ E.

m	t	s
0	28,0	34,05
10	28,2	33,96
20	28,4	34,18
30	28,2	34,08
50	27,4	34,31
58	26,3	34,38
77	24,8	34,61
115	23,9	34,63
153	18,3	34,57
192	15,2	—

Station Si. 20.
24. 8. 1949 15h
4° OO′ N, 126° OO′ E.

m	t	s
0	28,6	33,82
10	28,6	33,79
20	28,6	33,79
30	28,6	33,79
44	28,6	33,80
65	28,4	33,94
87	27,6	34,33
130	23,9	34,74
173	20,4	34,80
217	16,8	34,54

Station Si. 21.
25. 8. 1949 00h
5° OO′ N, 126° OO′ E.

m	t	s
0	28,5	33,83
10	28,9	33,76
20	28,7	33,79
30	28,5	33,94
44	28,4	34,13
65	27,0	34,50
87	25,1	34,63
130	20,4	34,77
173	18,2	34,76
217	14,4	24,53

Station Si. 22.
25. 8. 1949 09h
5° OO′ N, 127° OO′ E.

m	t	s
0	28,5	33,77
10	28,8	33,77
20	28,7	33,82
30	28,7	33,82
50	28,6	33,79
73	28,3	34,00
97	26,5	34,41
145	21,0	34,82
193	14,3	34,50
242	11,9	34,37

Station Si. 23.
25. 8. 1949 22h
4° OO′ N′ 127° OO′ E.

m	t	s
0	27,9	33,69
10	28,3	33,79
20	28,5	33,73
30	28,3	33,83
50	28,2	34,01
72	25,9	34,50
97	24,1	34,76
145	20,5	34,85
193	17,1	34,67
242	12,3	34,48

Station Si. 24.
26. 8. 1949 08h
3° OO′ N, 127° OO′ E.

m	t	s
0	27,0	33,54
10	27,2	33,39
20	27,0	33,48
30	27,0	33,52
44	27,0	33,47
65	26,8	33,63
87	26,0	33,94
130	18,8	34,65
173	17,7	34,62
217	16,5	34,55

Station Si. 25.
26. 8. 1949 18h
2° OO′ N, 127° OO′ E.

m	t	s
0	27,7	33,63
10	27,9	33,67
20	27,8	33,70
30	27,7	33,61
50	27,0	33,59
73	26,9	33,82
97	24,0	34,40*
145	19,1	34,59
193	16,6	34,51
242	14,0	34,42

Station Si. 26.
27. 8. 1949 04h
1° OO′ N, 127° OO′ E.

m	t	s
0	27,4	33,66
10	27,7	33,70
20	27,7	33,74
30	27,7	33,62
50	27,7	33,70
73	27,3	33,86
97	24,2	34,02
145	19,4	34,54
193	16,4	34,48
242	14,3	34,40

Station Si. 27.
27. 8. 1949 17h
0° OO′ 127° OO′ E.

m	t	s
0	27,3	33,58
10	27,0	33,59
20	26,8	33,60
30	26,6	33,55
50	25,7	33,78
75	23,9	34,04
100	21,3	34,36
150	17,6	34,45
200	14,7	34,37
250	12,9	34,38

Station Si. 28.
28. 9. 1949 02h
1° OO′ S, 127° OO′ E.

m	t	s
0	26,7	33,66
10	26,7	33,59
20	26,7	33,58
30	26,7	33,66
50	27,0	34,95
75	26,1	34,12
100	23,8	24,20
150	21,9	34,43
200	16,8	34,50
250	13,7	34,44

Station Si. 29.
28. 8. 1949 12h
1° OO′ S, 126° OO′ E.

m	t	s
0	26,7	34,02
10	26,7	34,09
20	26,6	34,01
30	26,6	34,03
50	26,6	34,01
54	26,5	34,02
71	26,4	34,02
106	24,8	34,09
142	23,0	34,32
177	20,7	34,45

Station Si. 30.
28. 8. 1949 21h
1° OO′ S, 125° OO′ E,

m	t	s
0	27,6	33,79
10	27,6	33,78
20	27,3	33,79
30	26,9	33,70
50	26,7	34,05
75	25,1	34,01
100	22,9	34,37
150	17,6	34,51
200	15,3	34,55
250	12,7	34,48

Station Si. 31.
29. 8. 1949 06h
1° OO′ S, 124° OO′ E,

m	t	s
0	26,2	32,74
10	26,2	33,37
20	26,5	33,59
30	26,0	33,82
50	24,7	34,11
58	23,4	34,37
77	22,8	34,40
115	19,5	34,57
153	16,6	34,45
192	14,0	34,41

Station Si. 32.
29. 8. 2949 15h
0° OO′ , 124° OO′ E.

m	t	s
0	26,5	28,26
10	27,2	32,09
20	27,4	33,23
30	27,3	33,34
50	26,6	33,72
75	25,7	33,71
100	23,7	34,18
150	20,6	34,54
200	15,5	34,51
250	12,7	34,48

Station Si. 33.
30. 8. 1949 00h
0° OO′ , 125° OO′ E.

m	t	s
0	27,3	33,54
10	27,4	33,56
20	27,3	33,57
30	27,3	33,62
50	26,8	33,59
73	25,3	33,93
97	23,7	34,21
145	21,9	34,50
193	15,2	34,47
242	13,0	34,46

Station Si. 34.
30. 8. 1949 09h
0° OO′ , 126° OO′ E.

m	t	s
0	26,8	33,56
10	27,1	33,68
20	27,0	33,59
30	26,4	33,83
50	26,0	33,88
75	24,2	34,04
100	21,8	34,48
150	19,5	34,46
200	16,6	34,50
250	14,5	—

Station Si. 35.
30. 8. 1949 17h
1° OO′ N, 126° OO′ E.

m	t	s
0	27,1	33,56
10	27,3	33,55
20	27,2	33,55
30	27,1	33,59
50	26,9	33,63
54	26,8	33,59
71	26,2	33,68
106	24,4	34,34
142	22,6	34,43
177	19,8	34,54

Station Si. 36.
31. 8. 1949 02h
2° OO′ N, 126° OO′ E.

m	t	s
0	26,9	33,52
10	27,1	33,52
20	26,8	33,60
28	26,5	33,83
46	26,3	33,83
50	26,0	33,90
65	24,4	34,36
98	22,3	34,61
130	19,5	34,60
164	16,8	34,48

Station Si. 37.
3. 9. 1949. 11h
1° 35′ N, 125° 05 E.

m	t	s
0	27,7	34,10
10	27,3	33,99
20	27,2	34,03
30	27,0	34,05
50	26,2	34,02
75	24,9	34,14
100	24,2	34,33
150	20,4	34,50
200	17,6	34,48
250	13,4	34,36

Station Si. 38.
3. 9. 1949 13h
1° 35′ N, 125° 30′ E.

m	t	s
0	26,1	33,74
10	26,3	33,78
20	26,1	33,81
30	26,0	33,93
50	25,3	34,14
65	25,1	34,13
87	24,2	34,35
130	21,6	34,55
173	18,7	34,49
217	15,6	34,42

Station Si. 39.
6. 9. 1949 22h
3° OO′ N, 128° OO′ E,

m	t	s
0	28,4	33,70
10	28,6	33,78
20	28,4	33,88
30	28,2	33,76
50	27,5	33,76
75	27,4	33,77
100	26,8	34,25
150	24,8	34,84
200	17,7	34,69
250	14,6	34,58

Station Si. 40.
7. 9. 1949 07h
3° OO′ N, 129° OO′ E.

m	t	s
0	28,5	33,39
10	29,1	33,87
20	29,0	33,97
30	29,0	33,90
50	28,8	34,06
75	28,8	34,19
97	26,6	34,80
145	23,6	35,39
193	18,9	34,98
242	16,4	34,82

Station Si. 41
7. 9. 1949 17h
3° OO′ N, 130° OO′ E.

m	t	s
0	30,9	33,78
10	29,5	33,77
20	29,4	33,91
30	29,3	33,91
50	29,3	34,05
75	29,0	34,13
100	28,8	34,31
150	26,6	34,82
200	25,7	34,87
250	21,4	34,95

Station Si. 42.
8. 9. 1949 03h
3° OO′ N, 131° OO′ E.

m	t	s
0	28,7	33,61
10	29,3	33,72
20	29,2	33,76
30	29,2	33,74
50	29,0	33,71
75	28,9	34,06
100	27,3	34,84
150	22,9	34,92
200	19,9	34,94
250	15,4	34,47

Station Si. 43.
8. 9. 1949 11h
2° OO′ N, 131° OO′ E.

m	t	s
0	29,4	33,48
10	29,2	33,64
20	29,2	33,79
30	29,1	33,88
50	29,1	33,87
68	29,1	33,95
91	28,9	34,51
136	24,7	34,94
182	21,9	35,05
227	17,5	35,01

Station Si. 44.
8. 9. 1949 21h
2° OO′ N, 130° OO′ E.

m	t	s
0	29,2	33,77
10	29,3	33,82
20	29,2	33,90
30	29,1	33,85
50	29,0	34,00
73	28,8	34,45
97	27,2	35,02
145	22,8	34,92
192	20,6	34,92
242	17,7	34,92

Station Si. 45.
9. 9. 1949 07h
2° OO′ N, 129° OO′ E.

m	t	s
0	28,7	33,92
10	28,9	33,85
20	28,9	33,86
30	28,9	33,83
50	28,8	34,18
75	28,7	34,50
100	26,6	35,22
150	21,7	35,17
200	17,5	34,96
250	15,5	34,72

Station Si. 46.
9. 9. 1949 18h
1° OO′ N, 129° OO′ E.

m	t	s
0	28,6	33,68
10	28,8	33,83
20	28,9	34,09
30	28,9	34,14
50	28,7	34,24
73	28,3	24,54
97	26,7	35,15
145	23,1	35,44
193	17,0	34,65
242	15,0	34,57

Station Si 47.
10. 9. 1949 04h
0° OO′ 129° OO′ E.

m	t	s
0	28,6	33,95
10	28,7	33,97
20	28,7	33,95
30	28,5	33,94
47	28,4	34,08
70	27,5	34,30
94	23,8	35,10
141	20,4	34,87
188	18,9	34,84
235	15,5	34,77

Station Si. 48
10. 9. 1949 15h
0° OO′ , 130° OO′ E.

m	t	s
0	28,9	33,94
10	28,8	34,17
20	28,6	34,16
30	28,6	34,19
50	28,5	34,45
75	26,6	34,67
100	26,2	34,67

Station Si. 49.
11. 9. 1949 01h
1° OO′ N, 130° OO′ E.

m	t	s
0	29,2	33,73
10	29,3	33,68
20	29,2	33,75
30	29,1	33,93
50	29,0	34,29
70	28,6	34,81
94	26,5	34,20
141	23,1	35,17
188	20,5	34,96
235	17,2	34,84

Station Si. 50
11. 9. 1949 11h
1° OO′ N, 131° OO′ E.

m	t	s
0	29,6	33,92
10	29,2	33,82
20	29,3	33,91
25	29,2	33,83
30	29,1	33,92
50	29,0	34,02
68	28,9	34,55
91	27,3	34,98
136	23,2	35,08
182	20,4	35,04
227	15,7	34,62

Station Si. 51.
11. 9. 1949 21h
1° OO′ N, 132° OO′ E.

m	t	s
0	29,3	33,67
10	29,4	33,64
20	29,4	33,69
30	29,3	33,88
50	29,2	34,02
75	28,5	34,66
100	26,8	35,03
150	21,7	35,02
200	17,7	34,79
250	15,1	—

Station Si. 52.
12. 9. 1949 07h
1° OO′ N, 133° OO′ E.

m	t	s
0	29,2	33,65
10	29,3	33,52
20	29,3	33,63
30	29,3	33,81
50	29,4	33,93
75	28,9	34,37
100	26,4	35,16
150	22,9	35,45
200	20,2	35,38
250	14,4	35,01

Station Si. 53.
12. 9. 1949 18h
1° OO′ N, 134° 00′ E.

m	t	s
0	29,7	33,85
10	29,3	33,89
20	29,3	33,87
30	29,1	34,10
50	29,1	34,15
71	28,7	34,36
94	28,0	34,90
141	23,9	35,47
188	19,8	35,40
235	15,6	35,01

Station Si. 54.
13. 9. 1949 04h
0° OO′ , 134° OO′ E.

m	t	s
0	29,1	32,84
10	29,2	33,72
20	29,1	33,86
30	29,1	34,06
50	29,0	34,07
75	28,9	34,31
100	27,4	34,80
150	22,6	35,40
200	19,2	35,25
250	16,9	35,15

Station Si. 55.
13. 9. 1949 13h
0° OO′ , 133° OO′ E.

m	t	s
0	29,6	33,42
10	29,3	33,86
20	29,2	33,91
30	29,1	33,96
50	28,9	34,18
71	28,4	34,50
94	27,6	34,52
141	25,1	35,35
188	22,7	35,40
235	17,1	34,76

Station Si. 56.
13. 9. 1949 23h
0° OO′ , 132° OO′ E.

m	t	s
0	29,0	33,59
10	29,3	33,67
20	29,3	33,73
30	29,2	33,83
50	29,0	34,06
75	28,8	34,23
100	26,5	35,06
150	23,2	35,31
200	19,4	35,01
250	15,2	34,78

Station Si. 57.
15. 9. 1949 04h
1° OO′ S, 130° OO′ E.

m	t	s
0	28,4	33,76
10	28,7	34,06
20	28,4	34,07
30	28,3	33,99
50	28,3	34,08
75	26,9	34,22
100	24,2	34,57
150	20,9	34,90
200	17,2	34,78
250	15,2	34,70

Station Si. 58.
15. 9. 1949 13h
1° OO′ S, 129° OO′ E.

m	t	s
O	28,7	34,06
10	28,7	34,06
20	28,5	34,11
30	27,4	34,46
50	26,8	34,48
75	25,1	34,88
100	23,0	34,98
150	21,6	34,96
200	18,4	34,89
250	15,9	34,76

Station Si. 59.
15. 9. 1949 22h
1° OO′ S, 128° OO′ E.

m	t	s
0	27,8	34,03
10	27,7	—
20	27,7	—
30	27,7	—
50	27,8	—
75	27,4	34,09
100	26,2	34,26
150	21,0	34,53
200	16,2	34,48
250	14,5	34,53

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